parkdc

PENN QUARTER/ CHINATOWN PRICING PILOT

Final Report | January 2019

GOVERNMENT OF THE DISTRICT OF COLUMBIA
MURIEL BOWSER, MAYOR

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16. Abstract

The parkDC: Penn Quarter/Chinatown Multimodal Value Pricing Pilot used the Penn Quarter/Chinatown neighborhoods of Washington, DC as a laboratory to test state-of-the-art strategies to make it easier to find a parking space. The project provided real-time parking-availability information so customers could spend less time searching and changed parking pricing (both raising and lowering prices) so more spaces were available. In addition, the pilot allowed DDOT to test a more cost-effective, "asset-lite" approach to collecting parking data.

The pilot was largely successful at achieving its goals. After four years and five price changes, parking availability increased on high-demand blocks and underutilized spaces found more takers; better information from DDOT helped drivers to understand when and where they could park, and where parking was available; and circling for parking and congestion decreased as finding parking became easier. DDOT began to address issues with double parking and illegal use of loading zones by applying pricing to loading zones. The pilot did not negatively affect local businesses and the pilot area still has high usage of non-driving modes. Lastly, the "asset-lite" approach was successful and enabled DDOT to conduct the pilot at lower cost and with fewer assets than the current state of the practice.

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parkDC: Penn Quarter/ Chinatown Parking Pricing Pilot

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Data Sources
Full data sources for the content of this document may be found within the parkDC: Penn Quarter/Chinatown Parking Pricing Pilot Data Book.

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The parkDC: Penn Quarter/Chinatown Parking Pricing Pilot (parkDC pilot) sought to use technology, pricing, and information to make parking easier and reduce congestion in part of downtown Washington, DC.

The parkDC pilot met the customer- and agency-related goals identified by DDOT at the pilot's outset. Due to the success of the parkDC pilot, DDOT is working to expand demand-based parking pricing to other District neighborhoods.

EXECUTIVE SUMMARY

The District's residents, commuters, and visitors all share one need: access to public curbside spaces.

The number and variety of customers sharing the District's curbside parking spaces is growing.

The District of Columbia is located at the center of one of the largest metropolitan areas in the United States. The resident population of over 700,000 people nearly doubles daily with an influx of over half a million commuters and over 125,000 visitors. These residents, commuters, visitors, and commercial vehicles all need access to public space, namely roads, sidewalks, and the curbside.

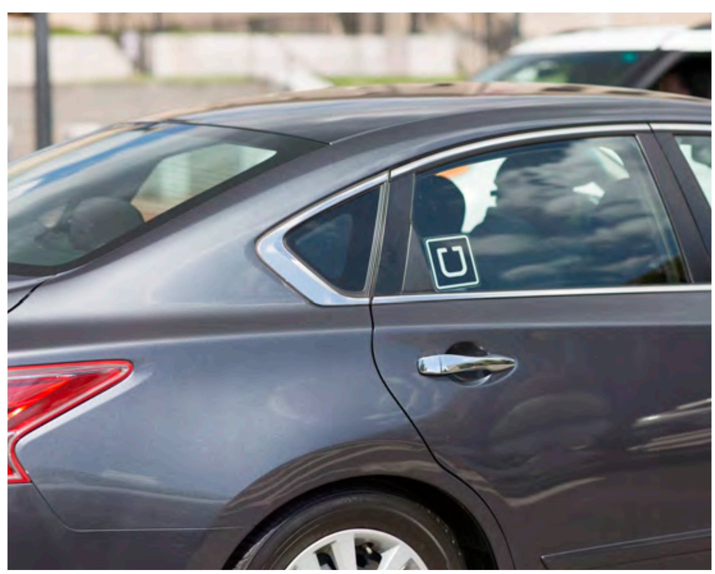
As a result, the District's on-street parking and curbside space is utilized by a diverse range of customers, ranging from personal cars to transit buses to commercial vehicles to taxis. The growth of new transportation options such as transportation network companies (mobile app-based ride hailing companies) are simultaneously expanding access to District neighborhoods and increasing demand for already limited curbside space. As the District's economy and population continue to grow, how the curbside is managed will help to shape how people and goods move.

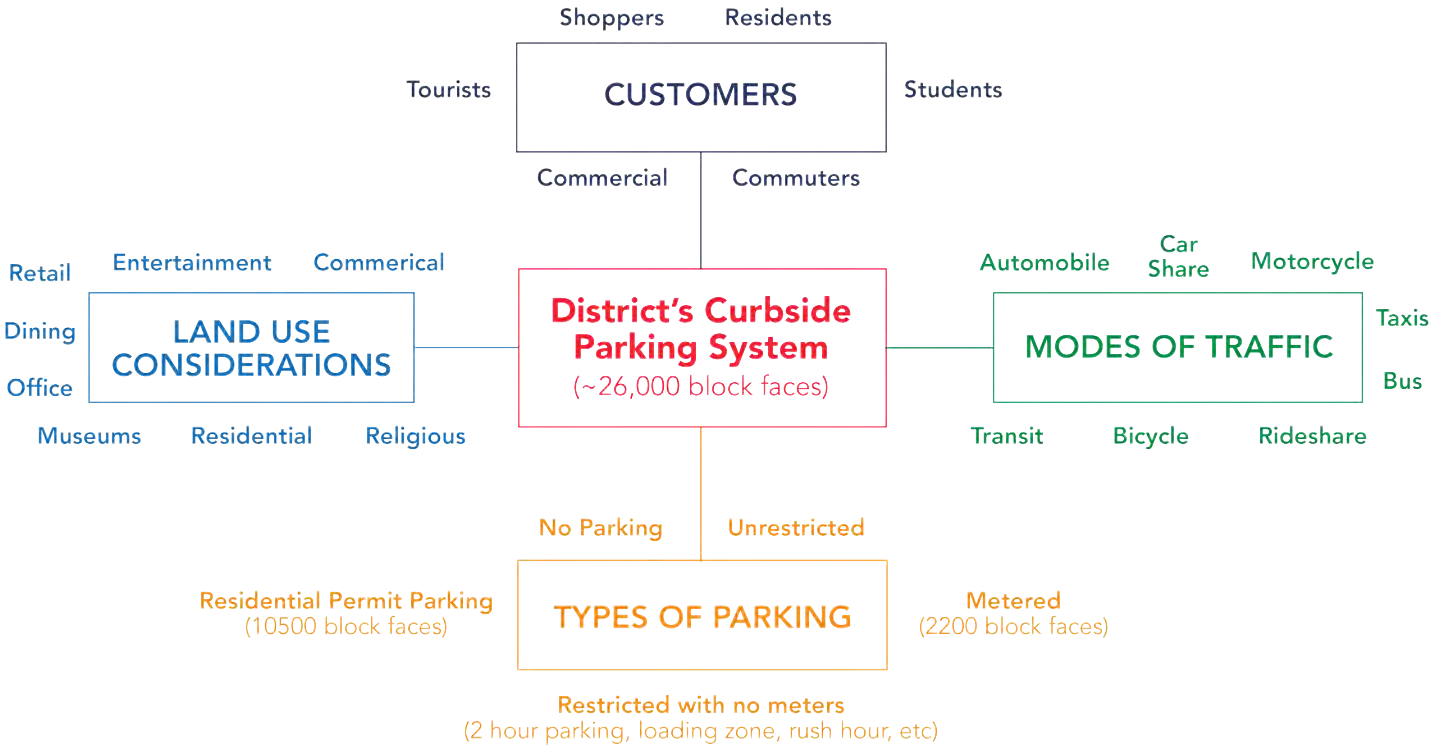
Customer challenges related to finding parking add to downtown congestion.

When demand outweighs supply for on-street parking, drivers are more likely to circle for parking or resort to parking illegally. The practice of circling for parking and parking illegally have both been identified as major contributors to congestion in the District. Illegally parked vehicles can block travel lanes, bicycle lanes, pedestrian crosswalks, and bus stops, leading to unsafe interactions between motorists, bicyclists, pedestrians, and transit users.

Limited information on parking availability contributes to frustration.

Customers often prefer on-street parking spaces for shorter durations since they are priced significantly lower than off-street garages. However, lack of visible information about the location of open spaces contributes to frustration.





Shoppers
Residents
Tourists
CUSTOMERS
Students
Commercial
Commuters
Retail
Entertainment
Commerical
Dining
LAND USE CONSIDERATIONS
Office
Museums
Residential
Religious
District's Curbside Parking System
(~26,000 block faces)
Automobile
Car Share
Motorcycle
Taxis
MODES OF TRAFFIC
Bus
Transit
Bicycle
Rideshare
No Parking
Unrestricted
Residential Permit Parking
(10500 block faces)
TYPES OF PARKING
Metered
(2200 block faces)
Restricted with no meters
(2 hour parking, loading zone, rush hour, etc)

Capital One Arena
TONIGHT
POLICE

Better information and demand-based pricing can help reduce the "agony" of parking downtown.

Across the transportation field, public agencies are increasingly turning to demand-based pricing to help manage access to scarce resources.

In the Washington, DC region, time of day pricing is used on the Metrorail system to help spread out peak demand. High-occupancy toll (HOT) lanes in Virginia use pricing to provide less congested travel to carpools, buses, and for a price, solo drivers.

Major urban areas have made the connection between roadway congestion and curbside management.

Simply adjusting time limits and pricing through spot applications on an as-needed basis does little to mitigate the practice of circling for parking and parking illegally, both of which contribute to roadway congestion. A more active, data-driven approach to curbside management with regularly updated parking pricing and policies helps to mitigate circling and illegal parking, and supports larger agency goals such as increasing network mobility and reducing system congestion.

Cities and towns are increasingly recognizing that parking pricing has an important role in addressing parking demand.

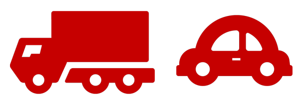
Pilots and programs in San Francisco, Los Angeles, Seattle, and Indianapolis, among others, have demonstrated that demand-based parking pricing is an important tool for parking management and has a positive impact on urban congestion.

Gathering parking demand data has been expensive.

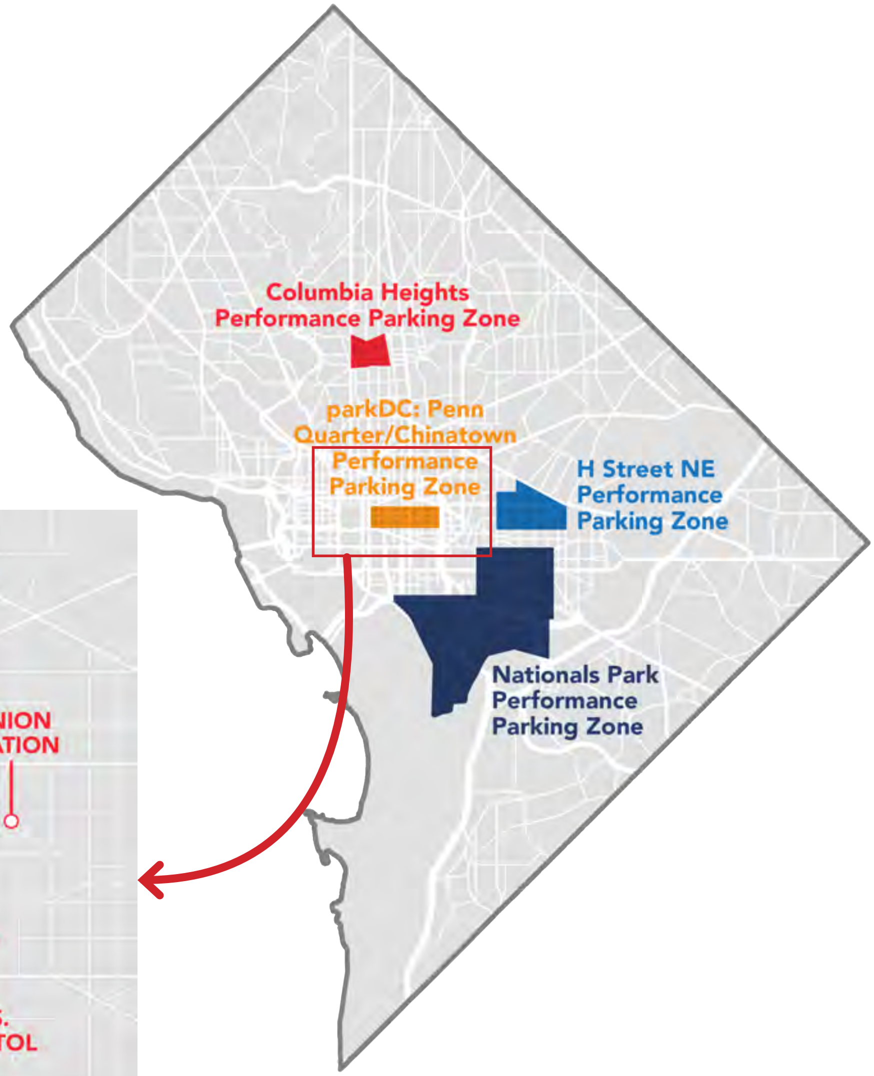
However, continued technological innovations and advances in big data analytics provide an opportunity to reshape the way agencies manage valuable curbside spaces at a fraction of the cost. These technologies also provide opportunities to look at other curbside space users, such as commercial vehicles and motorcoaches, and explore how pricing affects their activities.

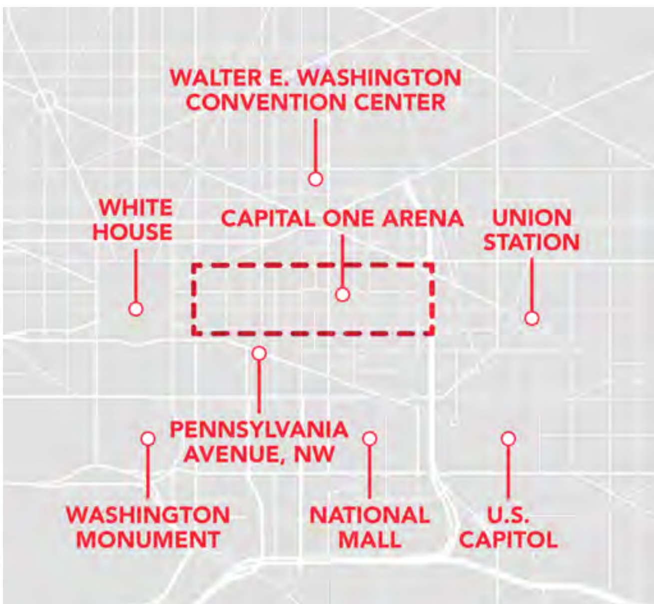
DDOT's parkDC: Penn Quarter/Chinatown Parking Pricing Pilot set out to improve curbside access from all user perspectives.

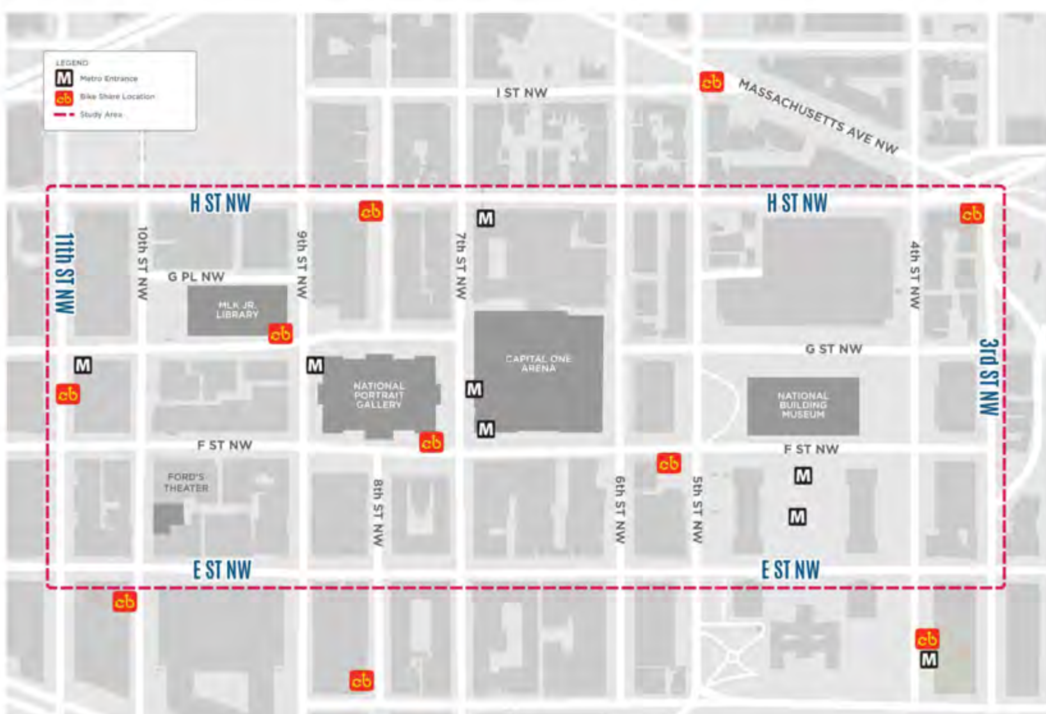
Building on the experiences of other agencies and with the support of a grant from the Federal Highway Administration's (FHWA) Value Pricing Pilot Program, DDOT set out to leverage technology and data to test demand-based parking pricing in the District's downtown. The parkDC pilot also sought to advance the state of the practice by applying a multimodal and asset-lite approach to the program. DDOT executed the pilot in the Penn Quarter and Chinatown neighborhoods from September 2014 to November 2017.

ADVANCING THE STATE OF THE PRACTICE	
 Multimodal	Apply pricing principles to other modes (i.e., commercial loading zones)
 Asset-Lite	Develop demand-based pricing and real-time parking availability information at a significantly lower price point by deploying fewer assets

The Penn Quarter/ Chinatown Pilot Area







DDOT's demand-based pricing pilot aimed to accomplish three goals:

Reduce time to find an available parking space

- Increase parking availability
- Provide parking availability information to customers in real time
- Improve parking regulatory signage

Reduce congestion and pollution, improve safety, and encourage use of other modes

- Reduce double parking
- Reduce circling for parking
- Encourage travel by other modes
- Improve operations of commercial loading zones

Develop parking management solutions through a cost-effective asset-lite approach

- Test different parking occupancy detection solutions
- Explore effectiveness of fusing data from various sources to provide real-time availability information and inform pricing algorithms with fewer deployed assets

This is how DDOT made it work.

Pricing.

DDOT applied demand-based parking pricing to on-street spaces in the pilot area. High-demand blocks have higher hourly prices to improve turnover, and low-demand blocks have lower hourly prices to incentivize greater use. In the parkDC pilot area, prices vary by block, side of the street (block face), day of the week (weekday vs. Saturday), and time of day (morning, midday, or evening). DDOT extended the concept of demand-based pricing to commercial loading zones.

DDOT changed prices in the pilot area five times between October 2016 and November 2017 based on ongoing monitoring of parking demand. DDOT developed price changes based on the prevailing District-wide base price for on-street parking ($2.30/hr.), and gradually increased the total number of price options over the five price changes. Prices increased on block faces where demand exceeded supply, decreased on block faces where supply exceeded demand, and remained constant on block faces where demand matched supply. Those blocks where demand matched supply would generally have one open parking space at any given time for drivers seeking to park in the area. Commercial loading zone pricing was based on the highest prevailing hourly rate on the zone's block.

PRICE CHANGE	RATE STRUCTURE (HOURLY RATES)								
Baseline				$2.30					
Round 1 *October 2016*			$2.00	$2.30	$2.75				
Round 2 *February 2017*		$1.50	$2.00	$2.30	$2.75	$3.25			
Round 3 *May 2017*	$1.00	$1.50	$2.00	$2.30	$2.75	$3.25	$4.00		
Round 4 *August 2017*	$1.00	$1.50	$2.00	$2.30	$2.75	$3.25	$4.00	$4.75	
Round 5 *November 2017*	$1.00	$1.50	$2.00	$2.30	$2.75	$3.25	$4.00	$4.75	$5.50

Time Limits.

Like parking pricing, adjusting the amount of time a customer is permitted to park in a curbside space can influence customer behavior and balance demand for curbside space. DDOT increased time limits in the evenings and on weekends in portions of the pilot area where demand was especially low to make those areas more attractive to parking customers.

Communication.

Information about parking availability can help customers to find an open parking space and enhance customer experience associated with finding a space. Two mobile apps, parkDC and VoicePark, developed as part of this pilot, provide customers with real-time information about parking availability and pricing. DDOT also tested new signage to reduce clutter and more clearly communicate on-street parking regulations. Calendar-style posters on every parking meter let customers know how much it costs to park based on the time of day and day of the week.

Outreach.

DDOT kept the public, policymakers, and other stakeholders informed about the progress of the pilot. Press releases, public presentations, DDOT's project website, social media channels, and other outreach tools helped DDOT raise awareness and collect feedback from residents, commuters, community leaders, and business representatives.

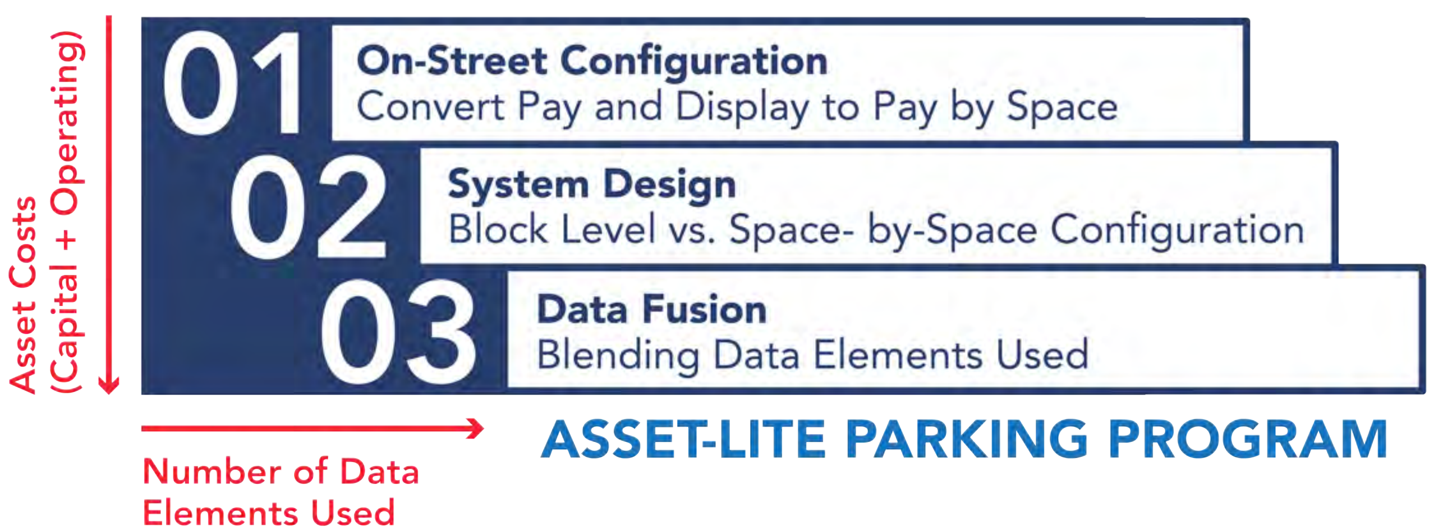
Technology.

DDOT's pilot program is designed to work and it is designed to last. Understanding real-time parking availability typically requires expensive data-collection technology. DDOT set out to design an "asset-lite" approach that would be sustainable from a cost and operations perspective. DDOT took a methodical approach to identify the right mix of data-collection technologies to support DDOT's demand-based pricing program with the fewest assets in the field.

The three steps of the asset-lite approach were:

1. **On-Street Configuration.** DDOT migrated to demarcated parking in the pilot area. Instead of being able to park anywhere between the signs on a block, this approach defined the spaces. By doing so, DDOT knew the total parking supply and how best to place and calibrate parking occupancy detection devices for maximum accuracy.
2. **System Design.** DDOT designed its demand-based pricing system to focus on the block face, not the individual space. Instead of collecting data in every single parking space, DDOT could strategically collect data in fewer locations and still predict on-street parking availability. Providing data at the block face level is good enough for a driver searching for an available space and for developing pricing strategies.
3. **Data Fusion.** DDOT reduced the number of devices that must be used to measure parking availability by combining data from multiple sources. Inputs ranged from in-ground parking sensors to parking payment data; different sources were tested to identify the right mix of data. By blending complementary data sources, DDOT was able to accurately measure parking availability while keeping the number of devices and costs down.

The data-driven, asset-lite approach allows DDOT to understand parking availability, develop price change recommendations, and communicate real-time traveler information to customers with half the assets typically deployed in the field.




LOADING ZONE
2 HOUR
PERMIT OR PAY TO LOAD
COMMERCIAL VEHICLES ONLY
Parkmobile
Zone: 24502
7AM-6:30PM
MONDAY-SATURDAY
IF TOWED CALL 311
TOW AWAY
NO PARKING
MOTORCYCLE
ONLY
7AM-7PM
MONDAY-SATURDAY
IF TOWED CALL 311
12041
YOUR PARKING ZONE#:
Located on the Meter
Register online or via mobile app:
www.parkmobile.com
Use our Mobile App
Parkmobile
PARKING MADE SIMPLE
APARTMENT

Pilot Successes

After four years and five price changes, DDOT evaluated how well the parkDC pilot met the original goals. The next three sections provide the outcomes for each of the three goals:

1. Reduce time to find an available parking space
2. Reduce congestion and pollution, improve safety, and encourage use of other modes
3. Develop parking management solutions through a cost-effective asset-lite approach

DDOT directly influenced customers' ability to find and pay for parking

Parking availability increased on high-demand blocks, and underutilized spaces found more takers.

At the start of the pilot, 62% of block faces had the desired level of usage (demand matched supply). This number increased to 72% at the end of the pilot. On high-demand blocks, occupancy stabilized as the price to park went up. When DDOT increased time limits in addition to lowering prices on low-demand blocks in the eastern portion of the pilot area, the blocks experienced a 12% increase in occupancy and a 14-minute increase in length of stay during weekday evenings.

Goal: Reduce time to find an available parking space

- Increase parking availability
- Provide parking availability information to customers in real time
- Improve parking regulatory signage

The pilot made parking easier to find.

The demarcated, pay-by-space environment guides customers to park more efficiently while pricing encourages turnover on high demand blocks. Customers parking in the pilot area self-reported a 7-minute decline in the time to find parking.

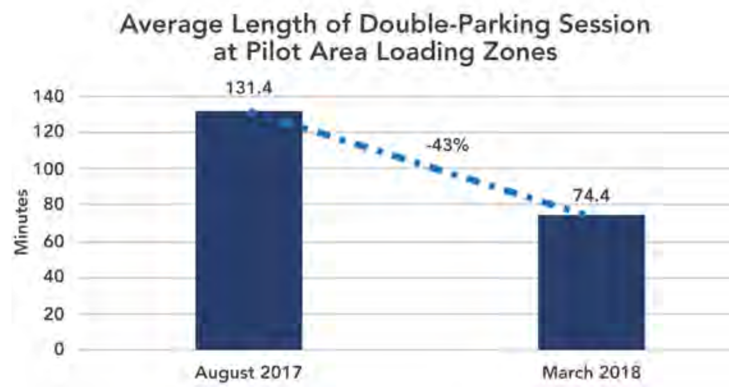
DDOT's communication strategy increased customer understanding.

DDOT improved how parking regulations and prices are communicated. Real-time traveler information apps and new parking signage improved the overall customer experience, with 15% more customers surveyed reporting that parking regulations and pricing are clear and easy to understand.

DDOT's pilot had positive secondary impacts on the broader transportation and land use network

As supply opened up, illegal parking decreased.

Double parking is a telltale symptom of high parking demand and low parking supply. Decreases in both citations issued for double parking and in the amount of time vehicles were observed double parking in loading zones point to the positive impacts of the pilot program on parking supply and demand.



Goal: Reduce congestion and pollution, improve safety, and encourage use of other modes

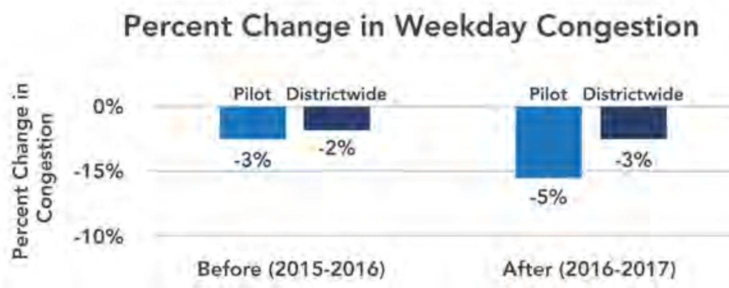
- Reduce double parking
- Reduce circling for parking
- Encourage travel by other modes
- Improve operations of commercial loading zones

Circling for parking decreased.

After DDOT implemented demand-based pricing, the amount of time vehicles spent cruising for a spot decreased by as much as 15% during all time periods on weekdays and weekends.

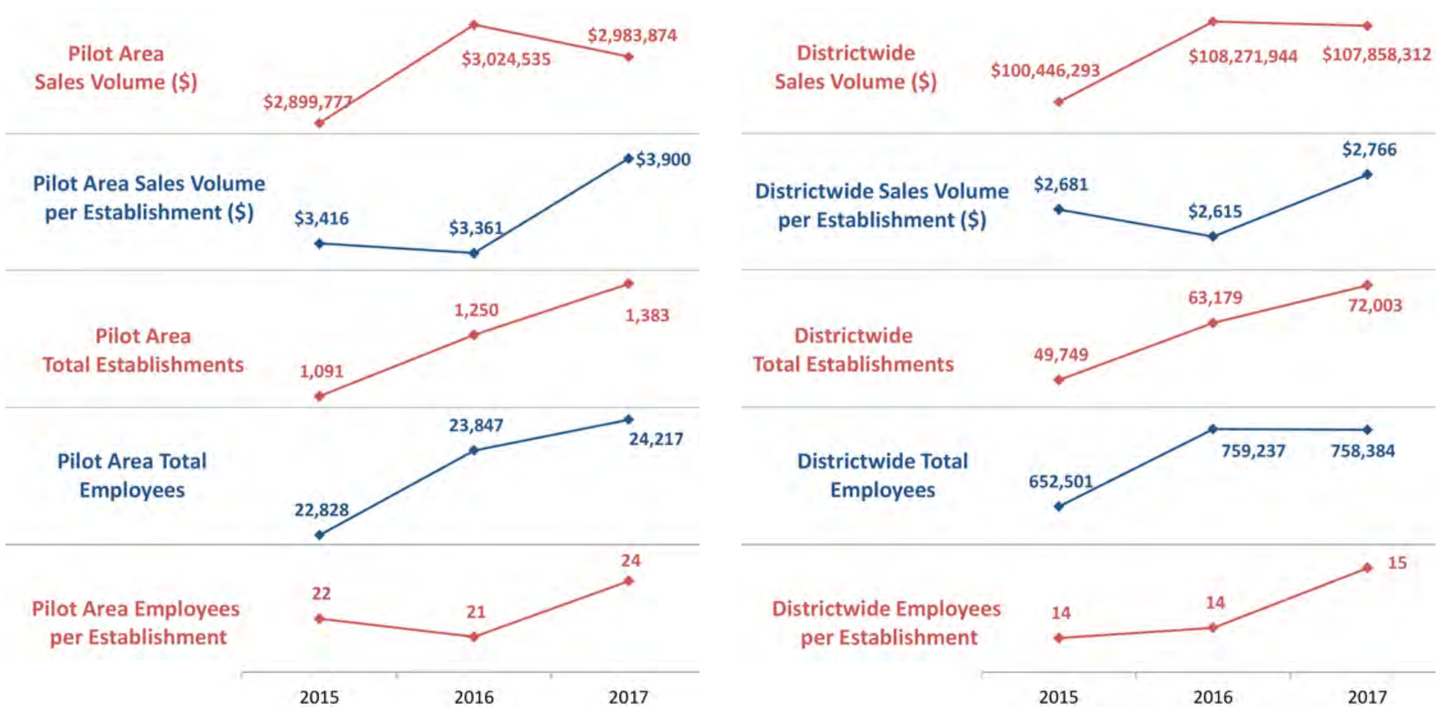
Congestion decreased and travel time reliability increased.

Weekday automobile congestion decreased by 5% and travel time reliability improved by 5% in the pilot area. Congestion trends in the parkDC area align with congestion trends Districtwide.



Economic access and vitality aligned with Districtwide trends.

Economic data from within the pilot area and Districtwide showed generally positive trends after the study. Positive trends in sales volume, employment, and the number of establishments in the parkDC pilot area aligned with trends Districtwide. These trends suggest that the pilot did not adversely affect economic vitality.



The pilot area continues to support many modes.

Multimodal data from the parkDC area showed largely positive trends after DDOT implemented the pilot. Capital Bikeshare ridership increased, bus speeds remained relatively stable, and bus ridership declined slightly, consistent with Districtwide trends. These trends indicate that DDOT's pilot did not hinder these modes and in some cases may have supported them. Despite ongoing interruptions related to system repair efforts, Metrorail ridership in the pilot area stabilized after DDOT implemented the parkDC pilot. This stable trend contrasts with systemwide activity, which continued a downward trend, and indicates that customers may have turned to transit based on better information about parking pricing and availability in the pilot area.

Change over time in Capital Bikeshare ridership in the pilot area

Safety impacts unknown but likely positive.

Although detailed safety data were not available for analysis during the pilot implementation period, the pilot's role in making it easier to find and pay for parking likely resulted in more predictable motorist behavior and fewer erratic movements.

DDOT developed a pilot program that meets agency needs

DDOT managed assets more effectively.

The pilot demonstrated that with pricing and time limit adjustments parking can be used as a demand management strategy for the District's metered on-street curbside spaces.

Goal: Develop parking management solutions through a cost-effective asset-lite approach

- Test different parking occupancy detection solutions
- Explore effectiveness of fusing data from various sources to provide real-time availability information and inform pricing algorithms with fewer deployed assets

DDOT successfully implemented a cost-effective, data-driven approach to managing on-street parking in two of the District's busiest downtown neighborhoods. DDOT took a "sandbox" approach to test a range of technologies and find the best fit from a technical and operational perspective. A partial deployment of sensors was successfully combined with a range of data sources, including transactions, historical occupancy data, and citations, to produce real-time availability information and inform pricing algorithms. The result was a technically viable, cost-effective occupancy detection and parking pricing program.


TOW AWAY
NO STANDING OR PARKING
7AM–9:30AM
4PM–6:30PM
MONDAY–FRIDAY
2 HOURS
Pay by Phone Parking
YOUR PARKING ZONE#:
21986
Register online or via mobile app:
www.parkmobile.com
To pay for parking:
Use our Mobile App
or Call 1-877-727-5758
Parkmobile
PARKING MADE SIMPLE
PNC BANK

The success of DDOT's pilot creates an opportunity to do more. Delivering the following steps in the next five years will help transform its parking management program.

Employ an incremental but intentional expansion plan:

- Expand demand-based pricing to other on-street spaces across the District, neighborhood by neighborhood, starting with areas most impacted by congestion
- Select neighborhoods for expansion based on data and analysis, including multimodal mobility data from DDOT's District Mobility project
- Identify a point-of-departure for on-street parking prices based on paid use, block by block
- Establish consistent time limit and pricing time periods Districtwide (exceptions should be established using data and analysis)
- Develop business rules related to pricing changes based on data and customer feedback to accurately reflect the expansion plan

Expand demarcated parking:

- Use demarcated parking at all metered on-street parking spaces across the District

Continue testing alternative technologies:

- Test emerging and alternative technologies such as automatic license plate readers (ALPR) and closed circuit television (CCTV) cameras
- Assess multiple vendors for the same technology to ensure that the District is served by the best in the business
- Establish a programmatic mechanism for piloting new technologies and testing new vendors, similar to the "sandbox" approach applied during the parkDC pilot
- Expand DDOT's proprietary system used to blend different occupancy data sources to incorporate new occupancy detection technologies
- Track evolving business models to ensure that DDOT's demand-based pricing program remains relevant
- Preserve flexible contracting and implementation to keep up with the ever-changing nature of the technology landscape

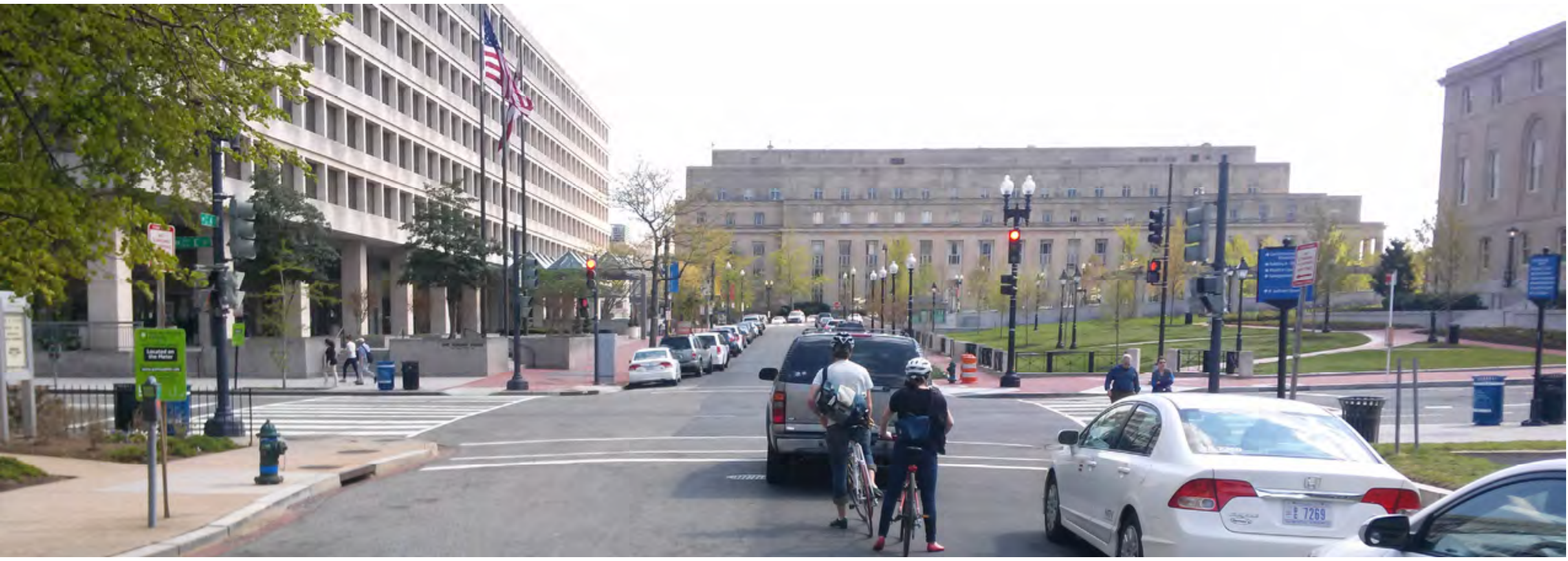
Move beyond on-street parking:

- Research and test strategies for managing parking in non-metered parking spaces
    - Consider strategies such as digital electronic permitting and the use of pay by cell zones for parking payments in residential neighborhoods
- Grow the parkDC pilot model to help locate disabled parking meters (Red Top meters), loading zones, and other unique uses for curbside space
    - Consider data-driven strategies for enforcing and understanding disabled parking and loading zone activity

CHAPTER 1

Overview

Framing our strategies and goals for the parkDC: Penn Quarter/ Chinatown Pricing Pilot.



1 Overview

The District's motivation and goals for the project, an outline of the strategies and technologies behind demand-based parking pricing, and the process used to assess the parkDC: Penn Quarter/Chinatown Parking Pricing Pilot's effects

1.1 PARKING FOR A GROWING DISTRICT

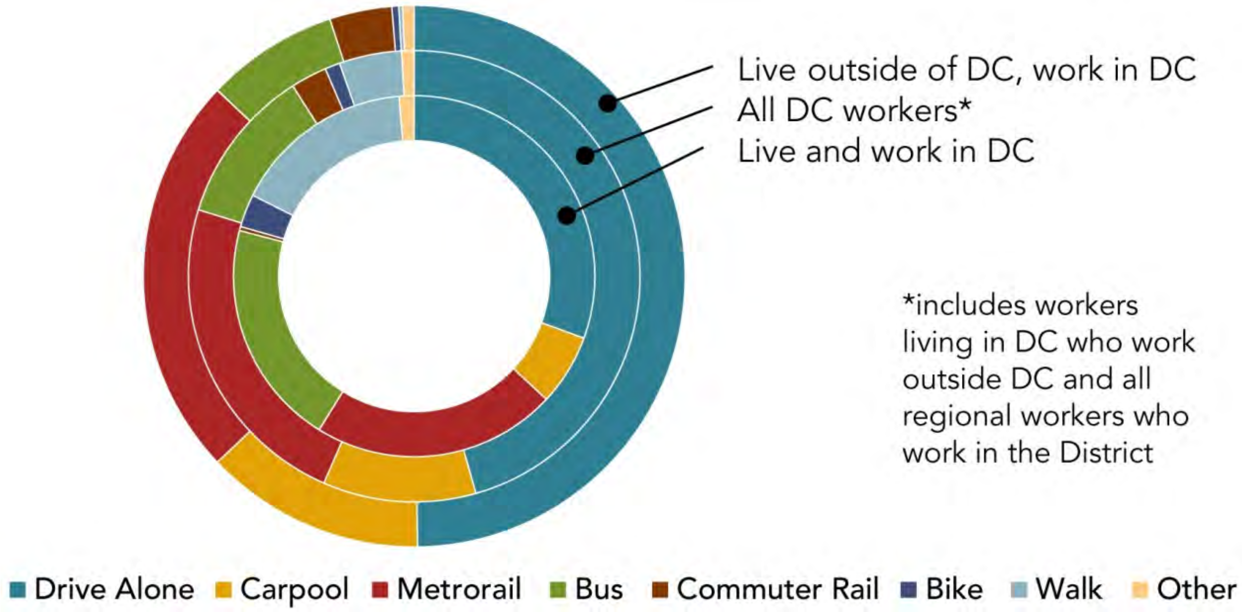
Washington, DC (referred to as the District) has experienced a sustained resurgence in housing and employment over the past decade. Due in part to its location at the center of the sixth largest metropolitan area in the United States, the District's population of over 700,000 almost doubles during daytime with an influx of more than 500,000 commuters and 125,000 visitors.[1] Although the District's multimodal transportation system is made up of robust transit, bicycle, and pedestrian infrastructure, many continue to travel by automobile. Over half of workers who live outside of the District travel to the District by car—whether alone or by carpool (Figure 1-1). In addition to commuters and visitors, the boom in online shopping and use of rideshare services has contributed to an uptick in commercial and individual demand

[1] District Department of Transportation. District Mobility: Multimodal Transportation in the District. January 2017. https://districtmobility.org.

for pick-up/drop-off zones and curbside loading zones.[2,3] Balancing the competing parking needs of residents, commuters, visitors, and businesses has been and will continue to be a growing challenge for the District.

Population projections for the region indicate that by 2040, approximately 150,000 more people will live in the District and overall employment will reach approximately 980,000 jobs. Growth in the urban core and surrounding region will increase the number of trips made within, to, from, and through the District. Quantifying, managing, and assessing parking performance along with other aspects of multimodal mobility will play a critical role in sustainably accommodating long-term growth and maintaining the District's competitiveness at a national level.

Figure 1-1. Commute mode share for workers in the District by place of residence (Census Transportation Planning Products, 2006-2010)



[2] Smith, A., and M. Anderson. *Online Shopping and E-Commerce*. Pew Research Center. December 2016. http://www.pewinternet.org/2016/12/19/online-shopping-and-e-commerce.

[3] Rutter, A., D. Bierling, D. Lee, C. Morgan, and J. Warner. How Will e-commerce growth impact our transportation network? *Texas A&M Transportation Institute Transportation Policy Research Center,* 2017. https://rosap.ntl.bts.gov/view/dot/32858

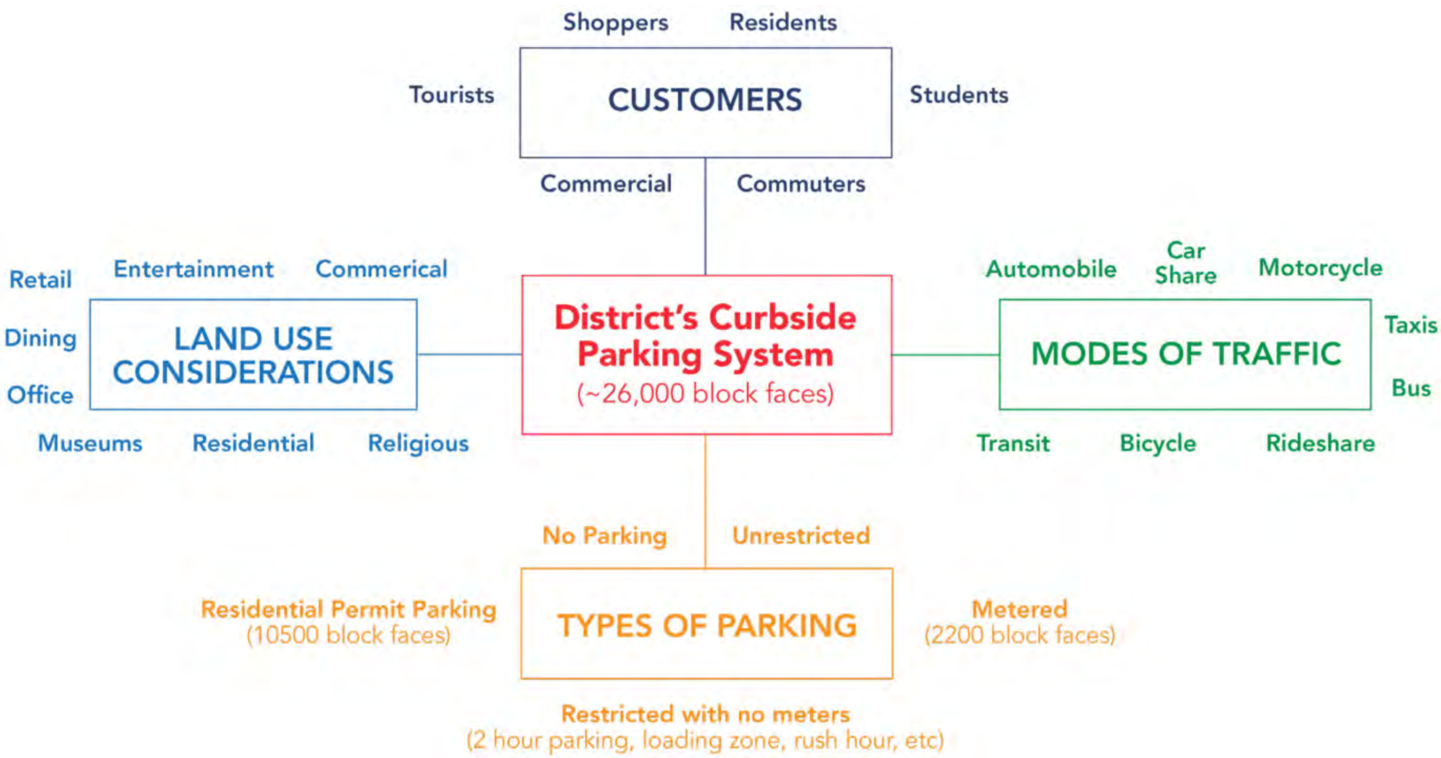
1.1.1 Pressures on the curbside

A city's curbside space is one of its most valuable resources. Proper management of this resource results in greater access, increasing the efficiency and functionality of the space for residents, visitors, and merchants alike. This in turn produces economic and quality of life benefits for everyone.

The District's on-street parking ecosystem is made up of a diverse range of customers in cars, on buses, and in commercial vehicles. The growth of new transportation options like rideshare services provided by Uber, Lyft, and Via is simultaneously expanding access to District neighborhoods and increasing demand for already limited curbside space, as shown in Figure 1-2. Often, these competing demands outstrip the amount of available space, requiring proactive management.

Competing demands need to be balanced by analyzing tradeoffs and looking closely at the local context. A solution that works in the downtown core may not be appropriate for a neighborhood center or low-density residential area.

Figure 1-2. Competing demands for limited curbside space



1.1.2 District Parking Assets

The District Department of Transportation (DDOT) manages approximately 1,375 miles of public curbside.[4] At the outset of the project in 2015, the public curbside was allocated to a range of uses, including:

- 100,000 residential permit parking spaces
- 19,000 metered parking spaces
- 1,000 reserved residential on-street Americans with Disabilities Act (ADA) parking spaces[5]
- 600 commercial loading zones
- 460 diplomatic parking spaces
- 450 on-street spaces for hotel guest loading
- 400 valet parking curb spaces
- 200 on-street motorcycle spaces
- 200 tour bus parking locations (on- and off-street)
- 100 reserved mobile roadway vending spaces and 72 stationary roadway vending spaces
- 84 dedicated on-street carshare spaces
- 6 on-street electric vehicle charging spaces

[4] Pérez, B. O. Delineating and Justifying Performance Parking Zones: Data-Driven Criterion Approach in Washington, D.C. Transportation Research Record: Journal of the Transportation Research Board, 2015. 2537: 148-157.

[5] 350 Red Top Meters that are reserved and accessible for the exclusive use of persons with disabilities were installed in the District's Central Business District in 2017.

Along with vehicle storage, the District's curbside accommodates over 3,500 bus stops, 13 Capital Bikeshare stations located in the curb lane, informal and evolving formal rideshare pick-up and drop-off locations, slug line (casual carpool) pickup sites, and the occasional pop-up park.

As of 2018, DDOT manages the District's 19,000 metered parking spaces with a mix of multi-space and single-space meters that are all network-integrated. DDOT offers customers three payment options at each parking meter – coin, credit/debit card, and pay by cell. The pay-by-cell program has been widely adopted by customers and accounts for over half of parking revenue; it is also the only way to pay for the use of on-street commercial loading zones.

1.2 MAKING THE CASE FOR PERFORMANCE PARKING

Cities and towns across the United States have increasingly identified demand-based pricing, or performance parking (henceforth referred to as demand-based pricing), as a useful tool for effectively managing public parking. Over many decades, the status quo of underpricing on-street parking has led to unintended consequences. Underpricing encourages motorists to cruise for parking when spaces are already occupied. It also encourages driving, disincentivizes use of off-street parking facilities, and discourages turnover at on-street spaces. Vehicles circling for parking or parking illegally contribute to increased congestion and safety concerns in vibrant downtown areas.

While US cities have long acknowledged that parking pricing should reflect demand, traditional, simplistic efforts to balance supply and demand have seen limited deployment. Jurisdictions may differentiate parking rates by neighborhood type, so that meters in central business districts are generally more expensive than in peripheral commercial districts. The District employed a similar pricing scheme in past years, charging $0.75 per hour outside the City's central core and $2 per hour within the core until June 2016. This approach can affect behavior in environments with relatively consistent demand and appropriately set prices, but homogenized pricing usually will not improve parking space utilization within a dynamic central business district.

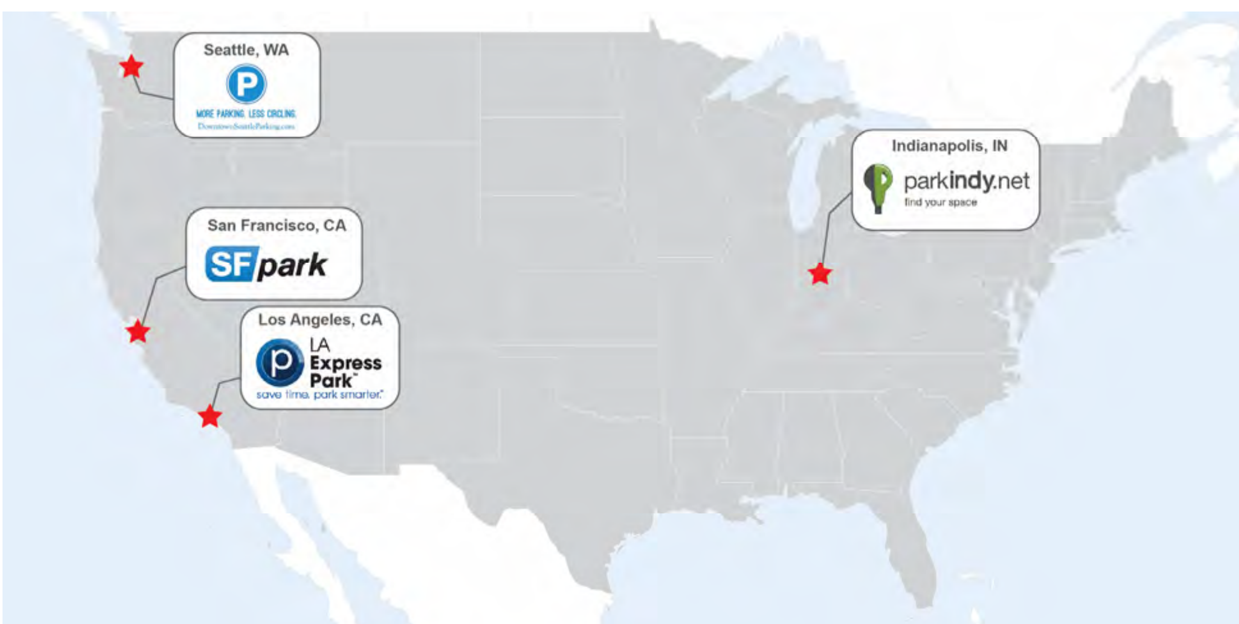
> Smart parking technologies and travel behavior data have transformed how cities approach curbside parking pricing.

Often, the role of local legislative bodies in setting parking prices limits the authority of local parking management entities to set prices based on demand. Jurisdictions that make the necessary legislative changes to set demand-based parking prices generally restrict the breadth of the price changes, in terms of prices and/or locations.

The advent of smart parking technologies and the growing availability of travel behavior data have transformed how cities approach curbside parking pricing. The transition to networked parking assets has enabled jurisdictions to use real-time transaction and citation data to inform operations and better understand demand. The growth of detection technologies ranging from in-ground sensors to mobile and fixed cameras has rapidly expanded the arsenal of available tools for gathering, analyzing, and fusing data from across the transportation system. Real-time monitoring and communication of occupancy information for curbside spaces enables travelers with smartphones to dynamically reroute to available spaces, reducing congestion and pollution caused by circling for parking. Smart parking technologies have also helped convince policy makers of the value associated with the legislative flexibility to set demand-based parking prices.

Pricing pilots in San Francisco, Los Angeles, Seattle, and Indianapolis have demonstrated how performance metrics from responsive data and technology can be successfully used to manage parking pricing and occupancy (Figure 1-3). As the District and other cities look to deploy or expand new smart parking initiatives, the experience from these cities has demonstrated that future pricing programs can afford to take a conservative, sustainable approach to price changes while still realizing the benefits of demand-based pricing.

Figure 1-3. Notable demand-based pricing programs in the United States

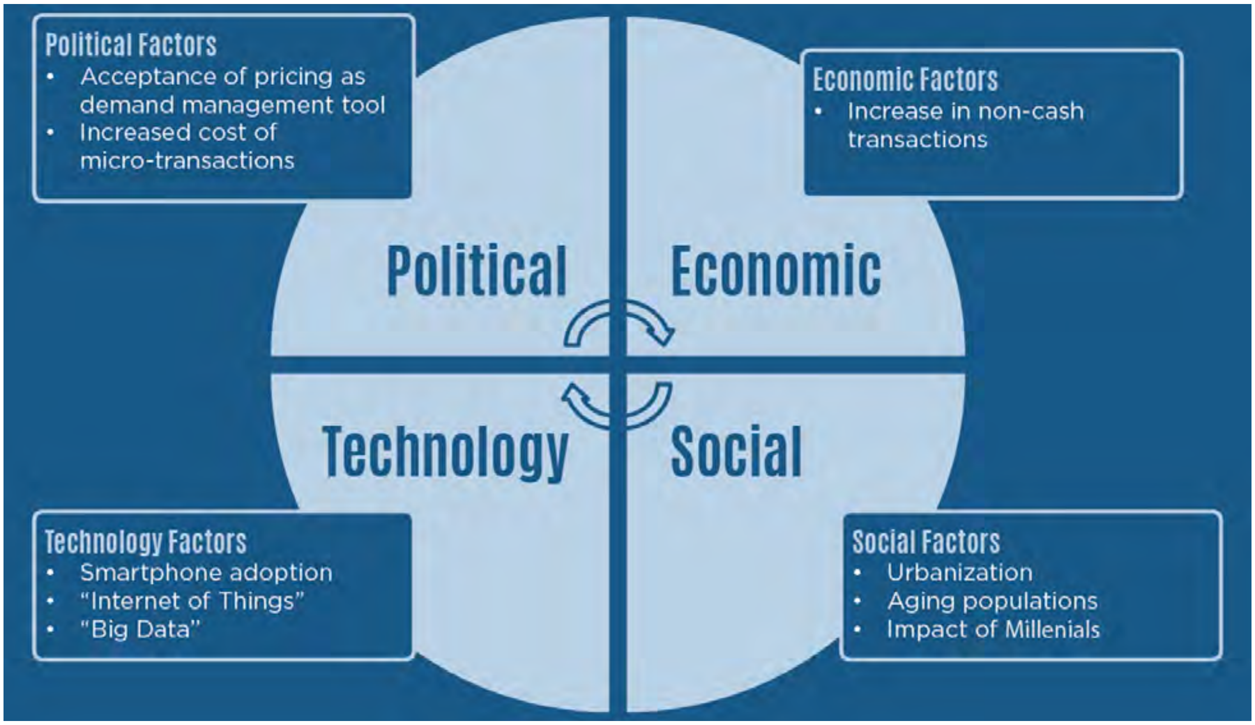


In addition to technological advances, a range of political, economic and social factors have contributed to the rise of demand-based pricing. As evidenced by the increasing popularity of high occupancy toll (HOT) lanes and demand-based transit fare structures, policymakers nationwide have accepted pricing as a demand management tool (Figure 1-4).

Figure 1-5 outlines some of the political, economic, social and technological factors that have made smart parking increasingly viable.

Figure 1-4. Demand-based roadway pricing has been implemented in Virginia in the form of high occupancy toll (HOT) lanes

Figure 1-5. Political, economic, social and technological factors have all contributed to the adoption of demand-based pricing



1.2.1 The District responds to curbside challenges

DDOT investigated demand-based pricing as a mechanism for addressing curbside challenges well before the technological advances that enabled San Francisco and other major US cities to implement their current programs. In 2008, the Council of the District of Columbia enacted vital legislation providing DDOT with greater flexibility to set and adjust meter rates and related enforcement days and hours, adjust parking fines, and establish zone-specific parking management targets in defined zones.

While the District was in the legislative vanguard of demand-based pricing, the technology needed to catch up. The District's 12-year transition to network-integrated parking meters between 2005 and 2017 enabled DDOT to estimate parking occupancy using payment transactions as a proxy. However, early payment data was not granular enough to distinguish meter usage patterns by block or meter. DDOT's successful application for federal funding from the Federal Highway Administration's (FHWA) Value Pricing Pilot Program made it possible to test new technologies and approaches for effectively measuring parking occupancy. The Program supports a variety of strategies to manage congestion, including tolling highway facilities through congestion pricing, mileage-based car insurance, and parking pricing. DDOT's grant application proposed to implement demand-based pricing to manage metered curbside spaces in the District's congested downtown business district and tourist areas. DDOT applied the FHWA funding to a next generation application of demand-based parking pricing: the parkDC: Penn Quarter/Chinatown Parking Pricing Pilot (parkDC Pilot).

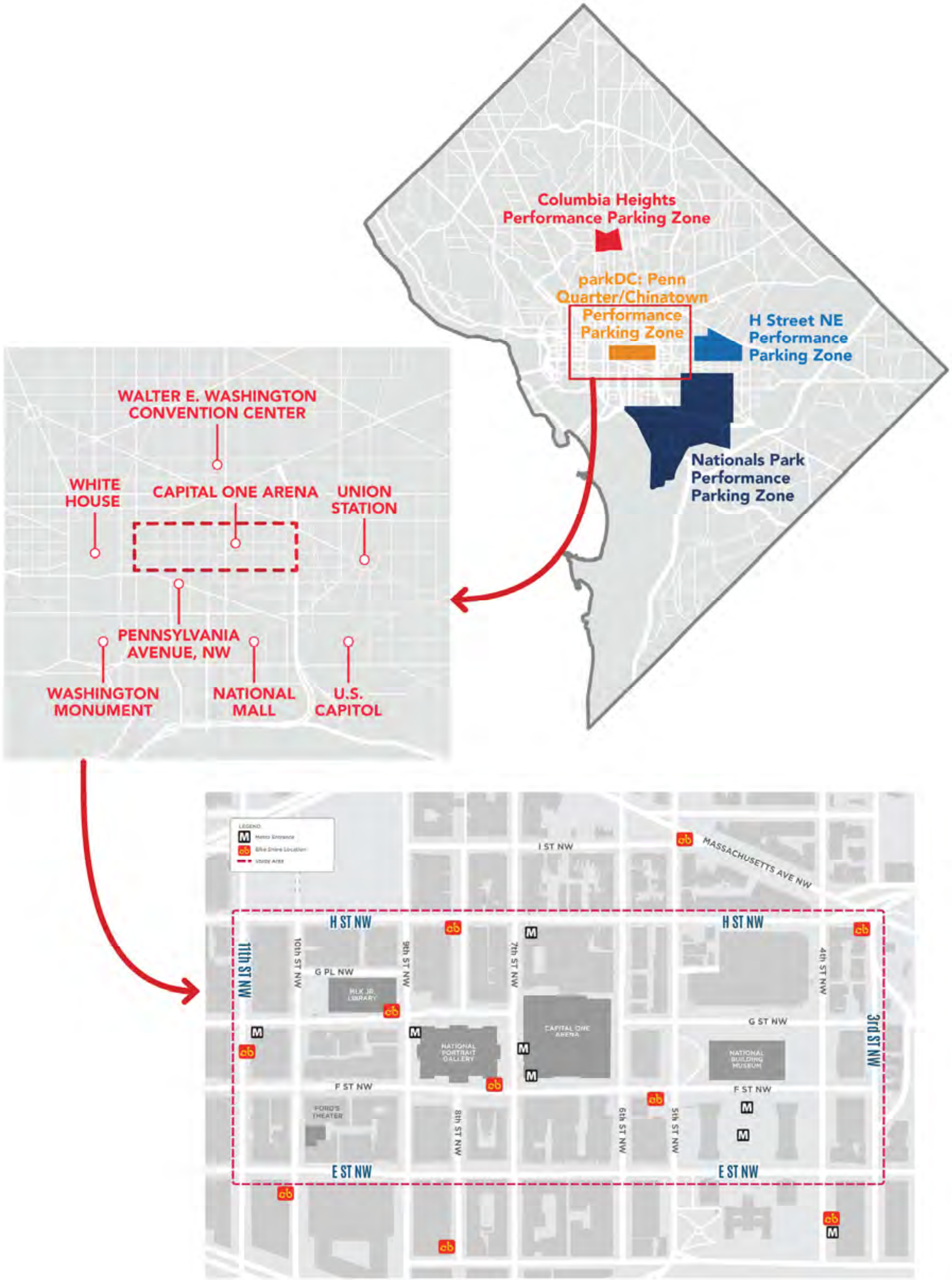
Through the parkDC Pilot, DDOT aimed to advance the state-of the practice for parking performance pricing in two ways:

- **Multimodal Focus**. Applying pricing principles to loading zones in addition to passenger vehicles
- **Asset Lite Approach**. Developing the program at a significantly lower price point than current state-of-the-practice.

1.3 TAKING THE NEXT STEP: THE PARKDC: PENN QUARTER/CHINATOWN PRICING PILOT

After obtaining the FHWA grant, DDOT refined and implemented its demand-based pricing program. When developing the grant application for the pilot program in 2012, DDOT used predictive geography to select a diverse, congested, and vibrant pilot area with competing modes and land uses. The area chosen falls within the Penn Quarter and Chinatown neighborhoods (Figure 1-6).

Figure 1-6. The Penn Quarter/Chinatown Pilot Area



- The pilot area is in the heart of the District between the National Mall to the south, the White House to the west, the Convention Center to the north and Union Station to the east. Located within the Penn Quarter and Chinatown neighborhoods, it comprises three subareas, defined by the major Metro Stations serving them: Metro Center, Gallery Place/Chinatown, and Judiciary Square (Figure 1-7).

- The Metro Center subarea to the west encompasses commercial office space with ground level retail and a tourist hub featuring Ford's Theatre, numerous souvenir shops, and major tour bus stops. The central library is also located in this subarea.

- The Gallery Place/Chinatown subarea is an entertainment destination centered on 7th Street NW with bars, restaurants, nightlife, and the Capital One Arena. This subarea also overlaps the historic Chinatown neighborhood, with the famous Friendship Archway and an exclusive pedestrian phase (pedestrian scramble) at the intersection of 7th Street and H Street NW. The National Portrait Gallery draws additional visitors to this subarea.

- The Judiciary Square subarea to the east is home to various federal and municipal courthouses and large federal office buildings. This subarea also has residential buildings, the National Building Museum, and a connection to I-395 just outside the pilot area.

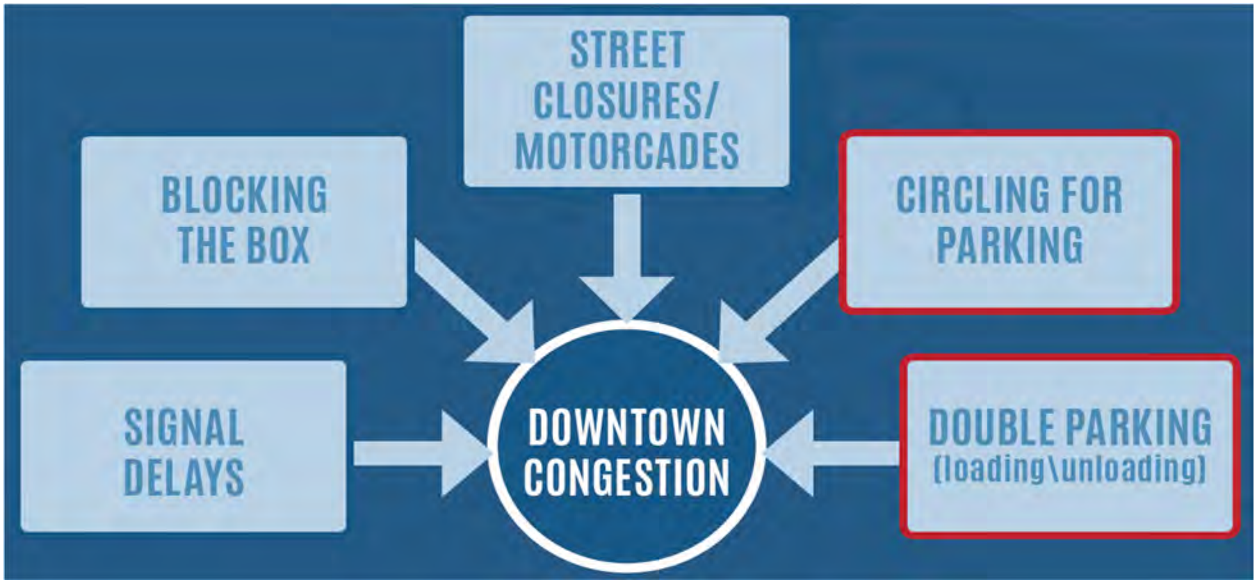
Figure 1-7. Pilot Area Subareas: Metro Center (west, mixed-use commercial), Gallery Place/Chinatown (central, mixed-use entertainment) and Judiciary Square (east, institutional)

The multimodal pilot area comprises 120 block faces and serves an array of residents and visitors. The pilot area is home to approximately 5,000 residents, 1,000 businesses and 23,000 employees. Many of the 21.3 million annual visitors to the District visit the pilot area to explore museums, attend sporting events, or enjoy a meal. The pilot area's transportation system supports this high demand by providing access to diverse transportation modes including:

Mode	Served by...
Personal Vehicles	A robust, gridded roadway network, 1,000 metered parking spaces, two reserved on-street car sharing spaces, and access to freeways and major arterials
Commercial Vehicles	30 on-street loading zones and 10 tour bus stops
Transit Vehicles	Three major metro stations and 38 bus stops
Bicycles	Six Capital Bikeshare stations and bicycle lanes on several streets crossing the pilot area
Pedestrians	A robust, gridded sidewalk network and active streetscape

The diverse land uses and multimodal character of the pilot area make it an ideal "sandbox" for testing a range of parking practices and innovations to rebalance parking supply and demand. Limited on-street parking that is underpriced compared to area parking garages and frequent motorist interactions with buses, pedestrians, and cyclists all contribute to the pilot area's parking puzzle. The diverse land uses within the area are an ongoing draw for residents and visitors, some of whom will continue to drive to the area despite limited parking supply. When demand for on-street parking outweighs supply, motorists inevitably end up circling the block to find a space and some resort to double parking. These behaviors contribute to downtown congestion and its associated ills, including safety concerns, air pollution, and economic inefficiency (Figure 1-8).

Figure 1-8. Factors contributing factors to downtown congestion



DDOT's initial site visits to the pilot area confirmed that circling for parking and double parking contribute to congestion in this already busy area. Film footage collected from automobiles and bicyclists showed how high demand for on-street parking can lead to double parked or illegally parked automobiles, commercial vehicles, and tour buses; unsafe conditions in on-street bicycle lanes; and aggressive vehicle maneuvers. While demand-based pricing cannot address every element contributing to downtown congestion, it can help to alleviate double parking and cruising for parking.

1.3.1 Setting our sights: project goals

DDOT's primary goal for the Penn Quarter/Chinatown Pricing Pilot was to improve the parking experience for customers by rebalancing parking supply and demand in the pilot area. DDOT aimed to meet this goal by using a mix of widely accepted parking practices, such as smart meters and alternative payment options, and cutting-edge techniques like real-time parking availability information and demand-based pricing (Figure 1-9). DDOT was able to pursue this goal because of the authority granted by the District Council to set and modify on-street parking prices (further described in Chapter 2).

Figure 1-9. The Smart Parking Spectrum

Widely Accepted	→	→	Cutting Edge
Smart Meters	Alternative Payment Options (pay-with-mobile devices)	Demand-Based Pricing	Real-time parking availability information

At the beginning of the pilot, DDOT developed a concept of operations plan to further outline the goals and objectives for the project (Figure 1-10), along with management and technical approaches required to achieve each goal.

Figure 1-10. DDOT Penn Quarter/Chinatown Pricing Pilot goals & objectives

Reduce time to find an available parking space

- Increase parking availability
- Provide parking availability information to customers in real time
- Improve parking regulatory signage

Reduce congestion and pollution, improve safety, and encourage use of other modes

- Reduce double parking
- Reduce circling for parking
- Encourage travel by other modes
- Improve operations of commercial loading zones

Develop parking management solutions through a cost-effective asset-lite approach

- Test different parking occupancy detection solutions
- Explore effectiveness of fusing parking data from various sources to provide accurate real-time availability information and inform pricing algorithms with fewer deployed assets

To meet these goals, parkDC sought to develop a system that uses an asset-lite approach and benefits all transportation modes. These two elements are described in the subsequent section.

1.4 WHAT MAKES PARKDC UNIQUE?

Municipalities like the cities of San Francisco and Indianapolis have successfully used occupancy detection to make demand-based price adjustments and provide real-time information to customers about parking availability and related topics. While the state of the practice for occupancy detection involves using assets such as sensors and cameras for every parking space, the parkDC Pilot tested a unique, new approach at a fraction of the cost. The pilot also tested the application of demand-based pricing principles other curbside uses such as loading zones. With this multimodal, asset-lite approach, DDOT aims to develop a sustainable, cost-efficient model for occupancy detection.

1.4.1 The asset-lite approach and multimodal

DDOT's goal of cost-effectively estimating real-time parking occupancy precluded the typical practice of providing full sensor or camera coverage in the pilot area. Because the expense of installing and maintaining full sensor coverage outweighs the benefits offered by better pricing policies (Table 1-1), DDOT sought on an optimal mix of assets and coverage to develop a sustainable solution and leverage existing data and assets.

Table 1-1. Approximate year 2014 cost to implement the parkDC pilot using full sensor coverage[6]

	Cameras	Sensors
Example Capital Cost	$2.5 Million	$4.5 Million
Example Annual Operation Cost	$1 Million	$2 Million

DDOT's asset-lite approach develops reliable occupancy data using information from all parts of the parking ecosystem, including networked meters, enforcement data, and pay-by-cell transactions. Combined with a mix of periodic occupancy data collected from portable and fixed closed circuit television (CCTV) cameras and permanent occupancy data collected from strategically placed in-ground sensors, these data allow DDOT to generate accurate parking occupancy information using less equipment (Figure 1-11). The success of the process depended not only on the physical assets associated with DDOT's unique approach, but on the cooperation of other District agencies and partners for the installation, operation, and maintenance of the system.

Effectively implemented, the asset-lite approach provides a minimum viable product that allows DDOT and other jurisdictions to measure real-time occupancy, share real-time information with the public, and inform a pricing engine for parking spaces. Detailed information on DDOT's approach to developing, testing, and implementing its asset-lite approach can be found in Section 3.1.

[6] Soumya Dey PE, P. M. P. (2014). "Asset Lite" Payment Options and Occupancy Detection for Metered Curbside Parking. Institute of Transportation Engineers. ITE Journal, 84(6), 29.

1.4.2 Benefiting all transportation modes

The District's dynamic, multifaceted transportation system warranted project goals that address parking experiences for multimodal users (Figure 1-12). Goals and objectives for the pilot considered infrastructure for commercial vehicles, transit (bus and heavy rail), motorcoaches, bicycles, and pedestrians.

Figure 1-11. parkDC System Overview

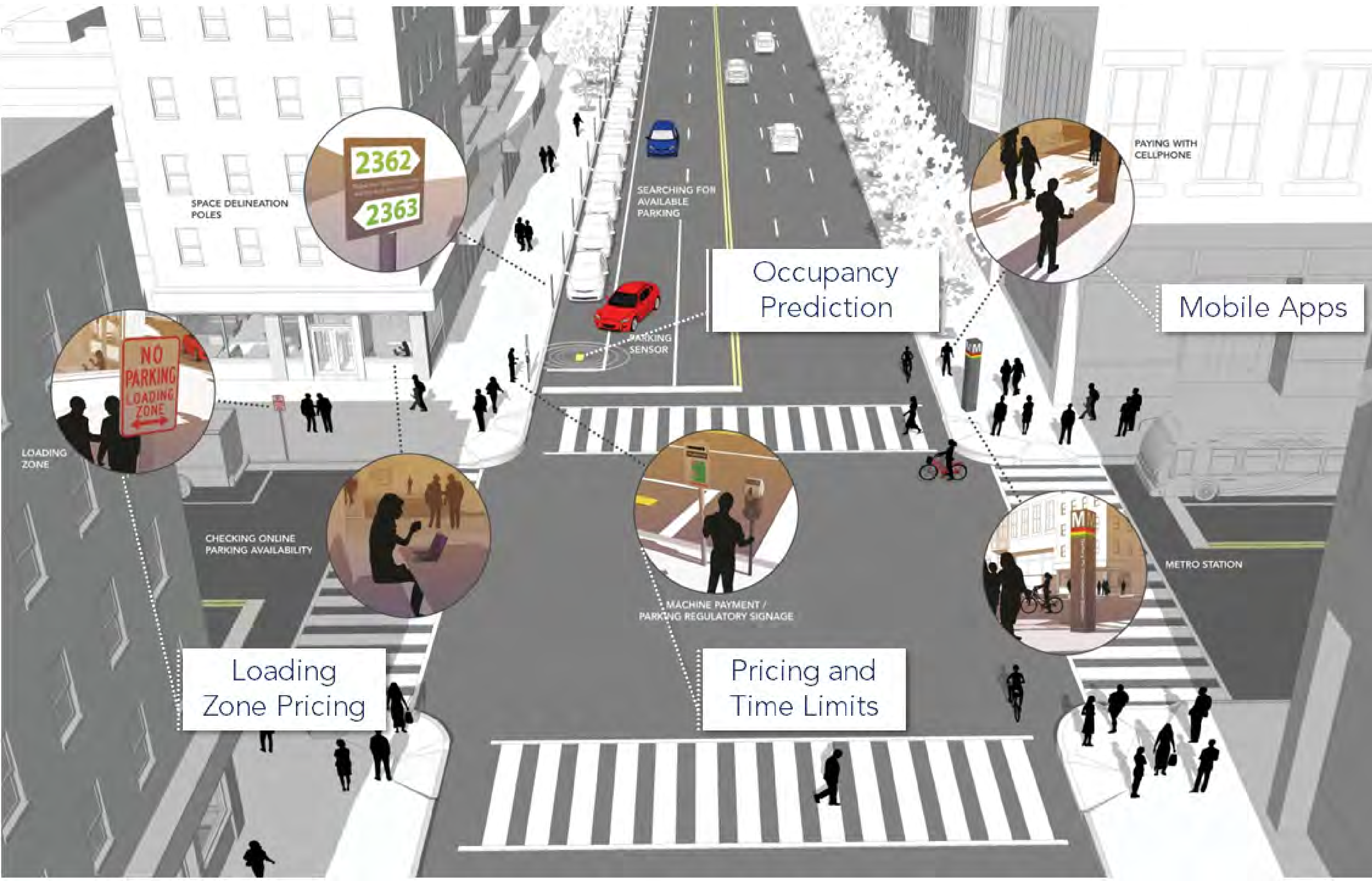
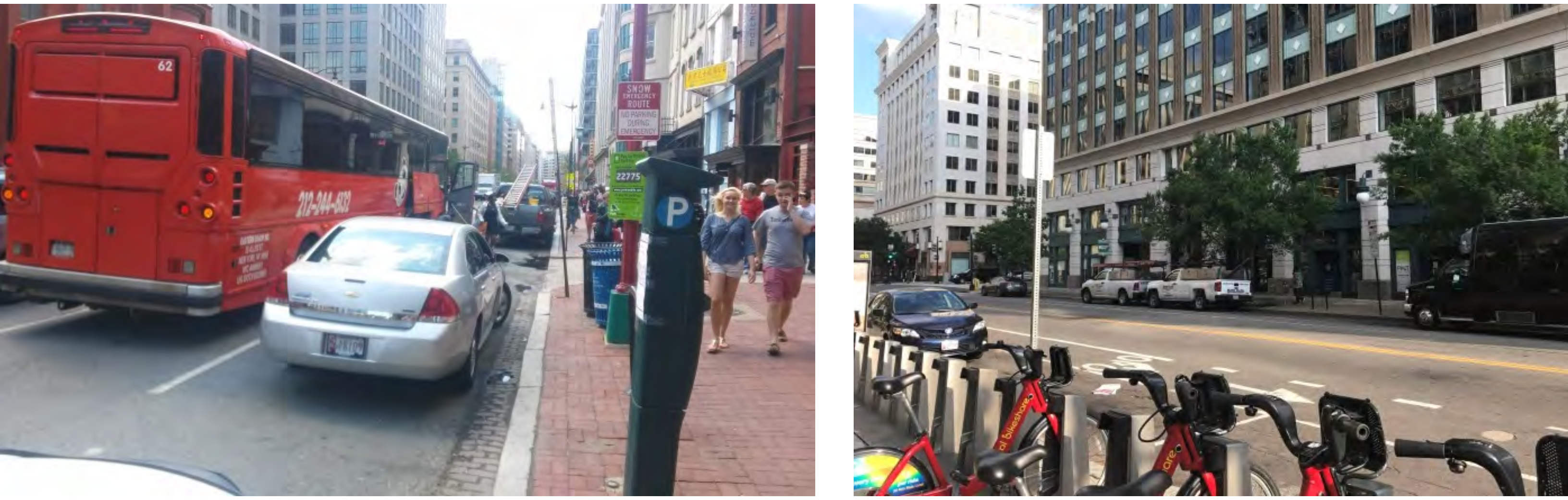


Figure 1-12. Multimodal Users in the Pilot Area



The strategies for benefiting multimodal users of the Penn Quarter and Chinatown transportation system were intertwined with those for balancing curbside parking demand and supply. An increase in on-street parking availability would reduce unsanctioned use of loading zones, bus zones, motorcoach parking, or bike lanes for parking or stopping by private vehicles. The availability of public roadway and curbside space for all multimodal users would further reduce disruptions to traffic flow by allowing multimodal users to efficiently access their designated spaces without blocking motorized travel lanes.

In addition to supporting multimodal travel by reducing double parking and circling for parking, DDOT sought to encourage higher transit use, particularly during high demand periods, through the provision of better information about parking availability. DDOT also endeavored to increase loading zone availability through demand-based pricing. DDOT aimed to more effectively balance the supply and demand of parking by acknowledging and seeking to influence these multimodal aspects of the parking ecosystem.

1.5 FROM LEGISLATION TO PILOT: THE PROJECT TIMELINE

The District Council approved the legislation that permitted the parkDC: Penn Quarter/Chinatown Pilot in October 2012. The FHWA grant funding that enabled the pilot was awarded to DDOT in August 2012, and DDOT officially kicked off the project in late 2014. The pilot project lasted four years and encompassed a pre-pilot phase and five price changes. DDOT developed a project management plan, concept of operations plan, system requirements plan, communication plan, and data collection plan during the pre-pilot phase to ensure that the pilot progressed on schedule and met all goals and objectives. Table 1-2 outlines the project timeline for the parkDC Pilot, along with major District events that likely impacted pilot results.

Table 1-2. Pilot Timeline (2014 – 2017)

Time Period	Pilot Activities	Districtwide Events
Q3 2014	▪ Project kickoff	
Q1 2015	▪ Prepared project management documentation ▪ Developed new signage	
Q2 & Q3 2015	▪ Used portable and fixed CCTV cameras to collect baseline data and inform asset-lite sensor deployment ▪ Tested in-ground sensors ▪ Transitioned to pay-by-space to collect accurate occupancy information from payment data	
Q4 2015	▪ Collected data and performed baseline conditions assessment	
Q1 2016	▪ Installed parking occupancy sensor equipment throughout pilot area	
Q2 2016	▪ Developed and tested pricing algorithm	▪ WMATA SafeTrack Program: segments of MetroRail lines were shut down or continuously single tracked for extended periods
Q3 2016	▪ Installed new signage ▪ Implemented first (round 1) demand-based price change (October) ▪ Provided real-time parking availability information through parkDC and VoicePark mobile applications	▪ WMATA SafeTrack Program continued
Q4 2016		▪ WMATA SafeTrack Program continued
Q1 & Q2 2017	▪ Round 2 price change (February) ▪ Round 3 price change (May)	▪ Presidential Inauguration (January) ▪ Implementation of Red Top Meter Program in District's Central Business District, reserving and pricing accessible on-street spaces for people with disabilities
Q3 2017	▪ Round 4 price change (August) ▪ Tested time limit adjustments (September) ▪ Implemented first loading zone price change (September) ▪ Performed after conditions assessment	
Q4 2017	▪ Round 5 price change (November) ▪ Completed comprehensive impact assessment	
2018	▪ Synthesized results of comprehensive impact assessment in pilot report, executive summary and data book ▪ Transitioned pilot to regular operations	

1.6 EVALUATING THE PILOT

DDOT used data gathered before, during, and after the parkDC: Penn Quarter/Chinatown Pilot to evaluate how effectively it met its stated goals and objectives. Data sources for the pilot covered multiple modes and ranged in granularity from location-specific, quantitative data points to area-wide, qualitative feedback. The data informed the before- and after-conditions evaluations detailed in Chapter 5. In addition to reporting on the success of the pilot in meeting its goals and objectives, DDOT used the data to evaluate the sustainability and replicability of the pilot beyond the Penn Quarter and Chinatown neighborhoods. Table 1-3 outlines the pilot's different metrics of success and associated data sources.

Table 1-3. Pilot evaluation metrics and data

Pilot Goal	Pilot Metrics	Data Source	Sample Data Sets
Reduce time to find an available parking space	Increased parking availability; increased use of low-demand parking spaces, decreased use of high-demand parking spaces	Parking sensors	Sensor "heartbeat" (parking session start/stop) data, uptime data, cost data, installation anecdotes
		Portable and fixed cameras	Parking session start/stop data
		Parking payment data (meters, pay by cell)	Payment session time, type and amount
	Increased clarity of regulatory signage	Customer surveys	Qualitative feedback collected through surveys distributed on meter receipts and DDOT social media accounts
	Increased dissemination of parking availability information	Mobile applications	Users, sessions, app crashes, average sessions per user, user devices, system performance statistics
Reduce congestion and pollution, improve safety, and encourage use of other modes	Reduced double parking	Parking citations	Citation type, location, and time
		Manual surveys	Surveys of double parking
		Portable and fixed cameras	Observations of double parking in loading zones
	Reduced circling for parking	Pole-mounted Bluetooth sensors	Cruising characteristics data collected via 59 Bluetooth sensors
		Manual surveys	Surveys of parking search time
		Probe vehicle archive	Congestion (travel time index) and reliability (planning time index) data from INRIX
	Encourage travel by other modes	Public transit operations (rail and bus)	Transit speed and ridership data from WMATA
		Bicycle	Bikeshare ridership data from Capital Bikeshare
		Census	Automobile ownership, single-occupant-vehicle (SOV) drivers, transit users, and bikers/walkers
	Improve operations of commercial loading zones	Portable and fixed cameras	Observations of activity in loading zones

Pilot Goal	Pilot Metrics	Data Source	Sample Data Sets
Develop parking management solutions through a cost-effective asset-lite approach	Test different parking occupancy detection solutions	Parking sensors	Sensor "heartbeat" (parking session start/stop) data, uptime data, cost data, installation anecdotes
		Portable and fixed cameras	Parking session data, installation anecdotes
	Explore effectiveness of fusing data from various sources to provide accurate real-time availability information and inform pricing algorithms with fewer assets in the field	Parking sensors	Sensor "heartbeat" (parking session start/stop) data, uptime data, cost data, installation anecdotes
		Asset-lite system outputs	System performance statistics (accuracy of occupancy data reported by asset-lite system)
		Parking payment data (meters, pay by cell)	Payment session time, type and amount

1.7 DOCUMENT ROADMAP

This report is divided into six chapters and an executive summary. This chapter—chapter 1—provides an overview of the project and background information on how and why DDOT sought to implement the parkDC pilot. Chapter 2 provides a summary of the planning and policy needed to enact the project, and chapter 3 describes how DDOT implemented the project. DDOT's efforts to coordinate with stakeholders and customers is presented in chapter 4. The impacts and results from the pilot are shown in chapter 5, with the conclusions, lessons learned, and next steps provided in chapter 6.

CHAPTER 2

Planning and Policy Framework

For performance parking to work, planning and policy must be in place.

2 Planning and Policy Framework

The sustainability and scalability of the parkDC pilot depended on a robust planning and policy framework, from early legislative changes enabling demand-based parking pricing to business rules detailing each price change.

2.1 ENABLING LEGISLATION

Like all departments of transportation, DDOT must maintain a nuanced understanding of legislation that can limit, enable, or maintain innovative projects such as the parkDC pilot. This section provides an overview of the legislative planning framework that evolved into the parkDC pilot.

2.1.1 Early Parking Legislation

As of 2010, the District used a simple, two-zone system to manage parking supply and demand. The practice of charging $2 per hour in dense, commercial zones and $0.75 in peripheral activity centers acknowledged the wisdom of pricing parking based on demand. However, a modern solution was needed to more proactively manage curbside parking in the District's densest neighborhoods.

2.1.2 The Performance-Based Parking Zone Pilot Act of 2008

The District Council enacted the Performance Parking Pilot Zone Act in late 2008 to allow DDOT to establish performance parking zones in the District. Key goals of the Act included:

- Preserve resident parking in residential zones
- Facilitate regular parking turnover in busy commercial areas
- Promote the use of transportation modes other than cars
- Decrease vehicular congestion

The Act gave DDOT the ability to establish zone-specific parking management targets and proactively set and adjust meter rates and related enforcement days, hours and fines near two large-scale developments in the District (the DC USA retail development and the Events DC Nationals Park).

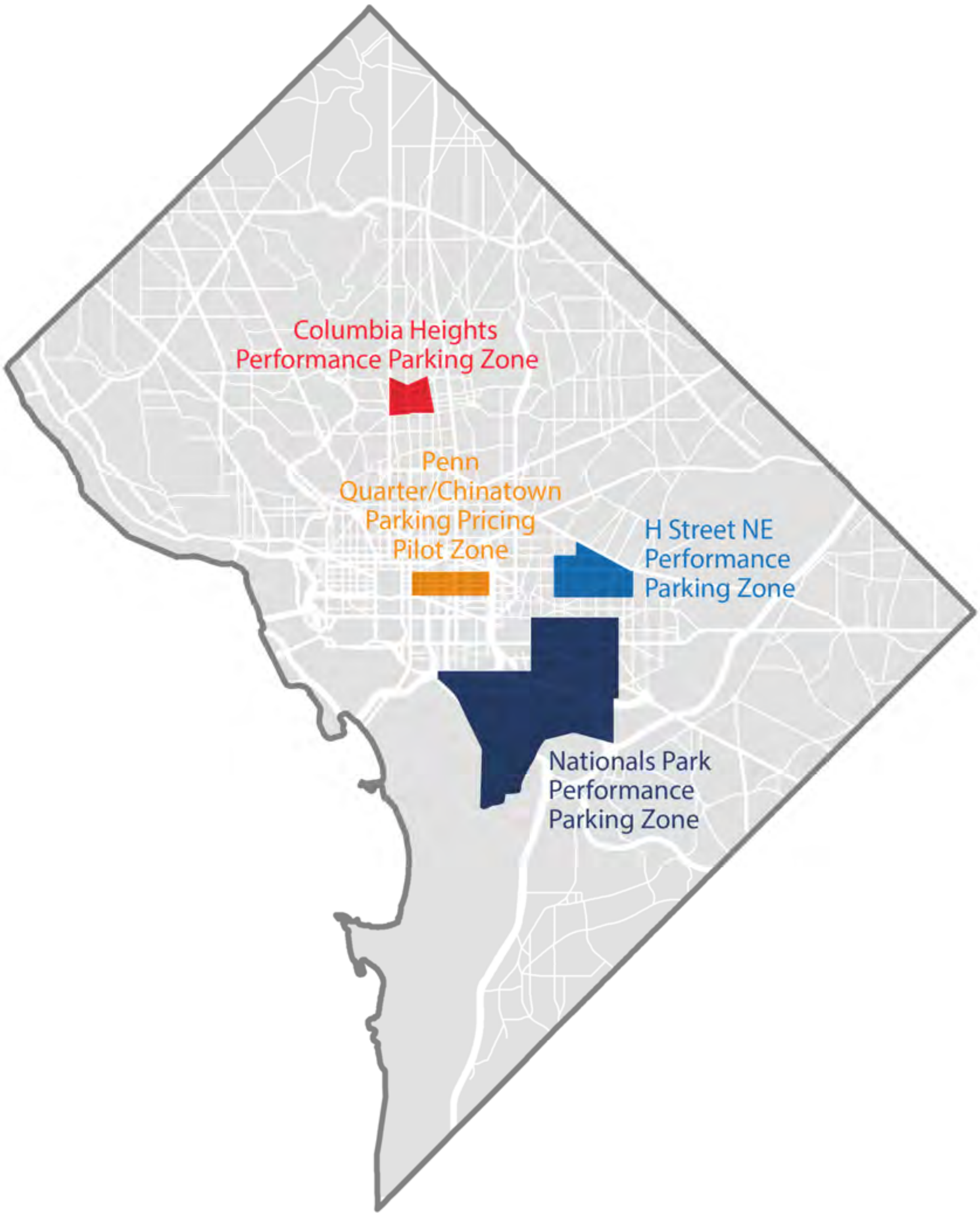
Since 2008, amendments to the Act have expanded DDOT's ability to apply demand-based parking practices in the District. The Performance Parking Pilot Zone Amendment Act of 2011 created the H Street northeast zone. In 2012, the Council enacted the Performance Parking Zone Expansion Amendment Act of 2012 (DC Law 19-168), which formalized the performance parking program and expanded DDOT's program authority to create new zones throughout the District.

2.1.3 The Parking Amendment Act of 2015

In 2015, the District Council further amended the 2008 Performance Parking Pilot Zone Act with the Parking Amendment Act of 2015 (DC Law 21-36). This amendment revised the 2008 action to limit once a month price increases to $1.50 in a three-month period, established an $8.00 per hour rate cap across the District, and identified the Penn Quarter/Chinatown pilot area as a performance parking zone area. As it relates to the pilot area, the act also allocated parking control and traffic control officers, set initial prices in the area equal to the existing parking meter fee in the zone, and set guidance to adjust parking fees to achieve 10% to 20% availability of curbside parking spaces.

Current performance parking zones in the District are shown in Figure 2-1.

Figure 2-1. Existing performance parking zones in the District



2.1.4 Districtwide Meter Rate Increase

On June 1, 2016 DDOT implemented a uniform, Districtwide parking meter rate adjustment to $2.30 an hour. The new meter rate was implemented as part of the Fiscal Year 2016 Budget Support Act. The meter rate applied to commercial loading zones and curbside meters across the District. The preliminary rate structure for the parkDC pilot was developed based on the new Districtwide base of $2.30 per hour.

2.1.5 Red Top Meter Program

DDOT implemented the Red Top Meter Program in May 2017 to increase the availability and accessibility of parking in the District for people with disabilities. Red Top Meters are parking meters with a distinctive red top that are accessible and reserved for the exclusive use of people with disabilities in the District's Central Business District, which encompasses the parkDC pilot area. The program requires payment from everyone parking at these meters but allows customers to park for 4 hours compared to the 2 hours typical at general use spaces. Prior to the implementation of the program, vehicles displaying a disabled placard or license plate were able to park for free for up to double the posted time limit. Red Top Meters support DDOT's goal of encouraging parking turnover and managing limited available curbside space in high-demand parking areas

2.2 POLICY DOCUMENTS AND BUSINESS RULES

The effectiveness of a complex, data-driven project such as the parkDC pilot depends on a comprehensive implementation and outreach plan. The parkDC project team codified implementation, outreach and program management processes for the pilot early in the project planning process. The detailed plans for each of these processes can be found in the parkDC: Penn Quarter/Chinatown Data Book.

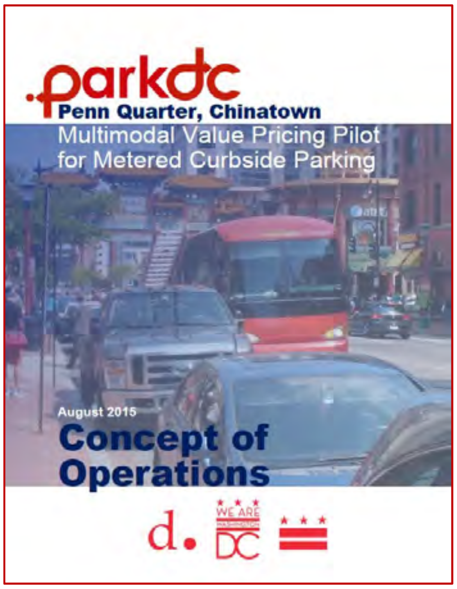
2.2.1 Program Management Plan

The program management plan described how the pilot team would manage the parkDC pilot and laid out a detailed approach to the management of scope, cost, quality, resources, communications, and risk to guide the team throughout the pilot.

2.2.2 Concept of Operations Plan

The Concept of Operations (ConOps) plan, as outlined in the *Systems Engineering ITS Guide*[1], framed the overall system and set the technical course for the parkDC project. It conveyed a high-level view of the system to be developed that all stakeholders could understand. The ConOps plan addressed the implementation of the roadway detection, parking detection, and variable pricing systems to be implemented as part of parkDC.

Figure 2-2. Concept of Operations Plan



2.2.3 Communication Plan

The communication plan outlined a range of strategies to engage stakeholders in the parkDC pilot and shape how the effort was perceived by stakeholders impacted by the project. The communication plan established goals and objectives, defined stakeholders, identified key messages, detailed an outreach plan, identified appropriate outreach materials, specified a timeline and outlined how the final results of the pilot would be presented to stakeholders.

2.2.4 Data Collection Plan

The data collection plan provided an overview of the data to be collected during the pilot and outlined how it would be used to measure the pilot's success. The collection and evaluation methods detailed in this plan were modeled on those used by SFpark. DDOT chose to use similar procedures so results of the demand-based pricing initiatives could be compared, and so that differences in system implementation would stand out in the results. DDOT was especially interested in observing how its asset-lite approach would affect pilot results compared to outcomes from other costlier implementation.

2.2.5 Parking Pricing Business Rules

DDOT developed parking pricing business rules to set clear guidelines for rate structure adjustments and communication processes for the pilot. The business rules also laid out the pilot's approach to accessible reserved metered parking for persons with disabilities (Red Top meters) and enforcement. The business

[1] USDOT, 2007

rules were updated throughout the pilot as DDOT developed and implemented changes, such as the loading zone pricing adjustments in the third quarter of 2017. Combined with the broader enabling legislation and pilot-specific policy documents, the parking pricing business rules form a solid foundation for future demand-based parking pricing zones, should DDOT choose to expand the program.

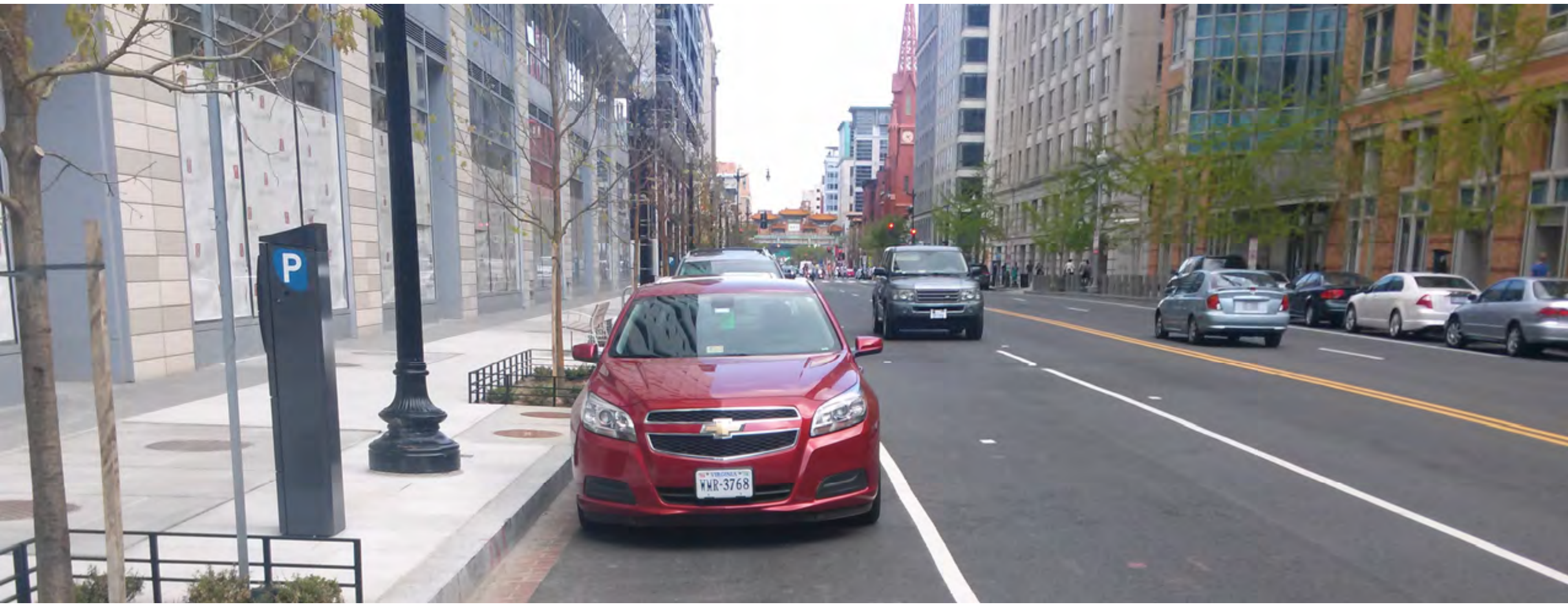
2.2.6 Supplementary Plans

DDOT developed several smaller, detailed plans to address the following project elements:

- **System Requirements Document**: memorandum describing the technical components of the pilot and its functional requirements.
- **Occupancy Detection Evaluation Plan**: memorandum outlining the testing plan for sensors and portable cameras deployed as part of parkDC.

CHAPTER 3
How DDOT Did It

Developing a cost-saving asset-lite approach to demand-based pricing took careful planning.



3 How DDOT Did It

Developing a cost-saving 'asset-lite' approach to demand-based pricing took careful planning. Here is how DDOT streamlined the approach other agencies have taken to measure real-time occupancy, share real-time information with the public, and appropriately price parking.

3.1 PARKING OCCUPANCY DETECTION: STATE OF THE PRACTICE

Parking occupancy is the fundamental building block for implementing a demand-based pricing program. Jurisdictions around the U.S. (Chapter 1) have used a range of data sources to measure parking occupancy, including parking meter payments and in-ground sensor data. Based on lessons learned about the limitations and benefits of different parking occupancy data sources and collection methods, DDOT pursued an asset-lite approach that blended occupancy data derived from a limited deployment of sensors with data elements from various sources. To increase the likelihood of the asset-lite strategy being effective, DDOT changed to a pay-by-space on-street parking configuration and developed a modified user interface for the parking availability app.

Before developing the asset-lite approach, DDOT assessed the benefits and drawbacks of two key sources of occupancy data used by other jurisdictions: meter payments and sensors. To date, most jurisdictions have used one data source to the exclusion of the other. The results of the assessment revealed the benefits and drawbacks of this approach.

3.1.1 Payment Data

Parking meter payments may provide a useful source of parking occupancy data. However, they do not necessarily paint an accurate picture of occupancy. Payment compliance rates vary significantly from city to city—often due to varying levels of disabled placard use and abuse, parkers exempt from payment (like police and government vehicles), and poor compliance because of inconsistent parking enforcement. Within a city, payment compliance can be highly variable from block to block, within a block, or by time of day.

3.1.2 Sensor Data

Cities across the U.S. have experimented with on-street sensors to measure parking occupancy. There are many benefits from such installations, including the potential to guide vehicles quickly to available parking, to direct enforcement, and, most importantly, to enable informed decisions about meter rates and time limits. Key limitations of sensor hardware include the high costs, increased maintenance needs, and rapid turnover of sensor technologies.

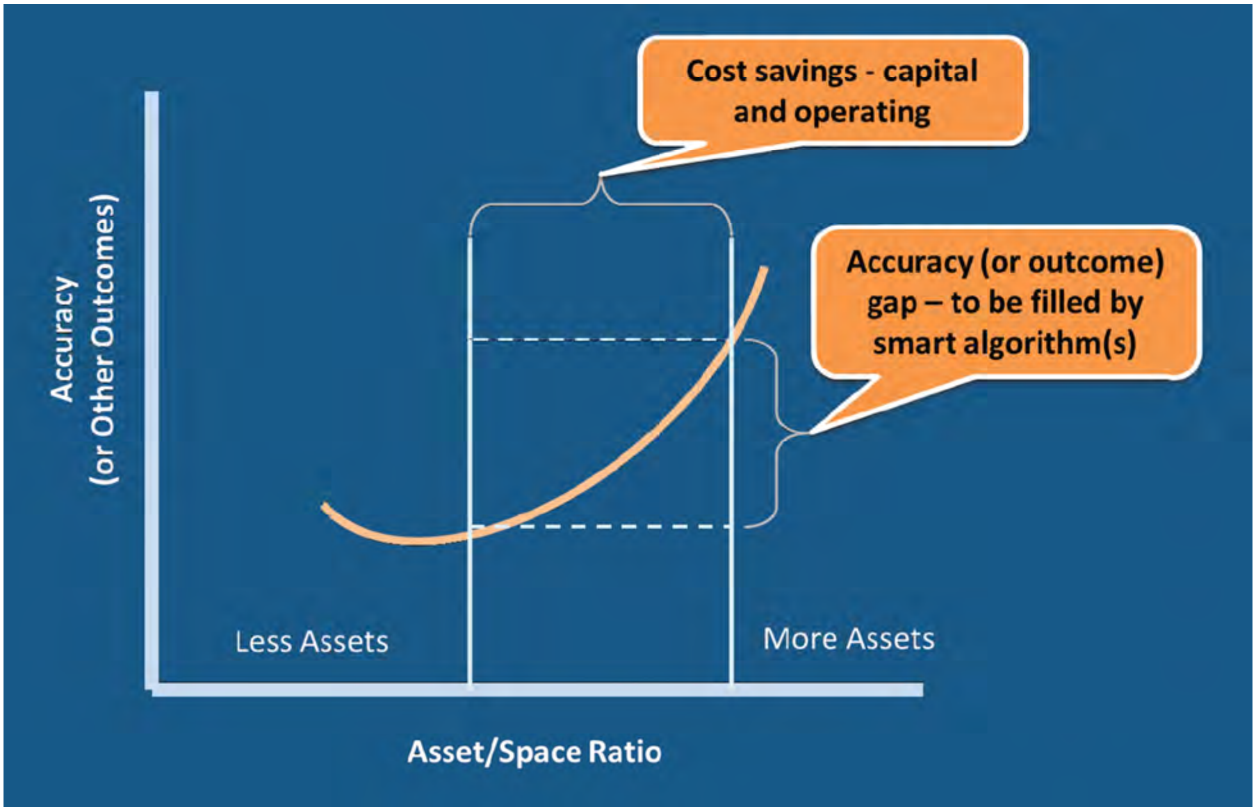
3.2 THE ASSET-LITE APPROACH

Rather than placing sensors in every parking stall or relying solely on meter payment data, DDOT tested the benefits of a blended approach of different data sources. DDOT posited that the pilot could reduce the number of sensors deployed by using meter payment data along with other data sources to extrapolate and fill gaps in the data, while also reducing the cost to operate the system. Reducing sensor coverage below 100% reduces data accuracy, but the effects can be mitigated through the following techniques:

- **Spatial sampling**, or observing only a fraction of the available spaces, and
- **Temporal sampling**, or observing blocks during different periods.

By fusing these sampling methods with payment data and other data from the parking ecosystem, like citations for metered parking, DDOT aimed to make accurate occupancy predictions in the pilot area and informed decisions about pricing (Figure 3-1).

Figure 3-1. The asset-lite approach aims to achieve the desired level of specificity in occupancy detection using fewer assets.



DDOT used a step-down method to identify the minimum viable product to meet the pilot's core needs, namely accurate parking occupancy predictions. The three steps are:

1. **On-street configuration**
2. **System design**
3. **Data fusion**

These three steps, shown in Figure 3-2, are discussed in more detail in the next three sections.

Figure 3-2. DDOT's step-down approach to monitoring and analyzing parking occupancy

3.3 STEP 1: ON-STREET CONFIGURATION

Since curbside parking is a finite resource it is imperative to design a system that informs the customer experience, promotes sustainability, and maximizes supply. With this in mind, DDOT chose to convert to a demarcated parking arrangement. Demarcated parking defines the parking stalls along the block with paint, poles, or single-space meters. Demarcating parking spaces fixes the location of vehicles along the curb and fixes the parking supply. These changes improve the accuracy and usefulness of occupancy data collected by sensors and meter payments.

DDOT converted the on-street parking configuration in the pilot area to demarcated parking using poles with space numbers on the sidewalk (Figure 3-3). The conversion to pay-by-space took place in May 2015 (Figure 3-4).

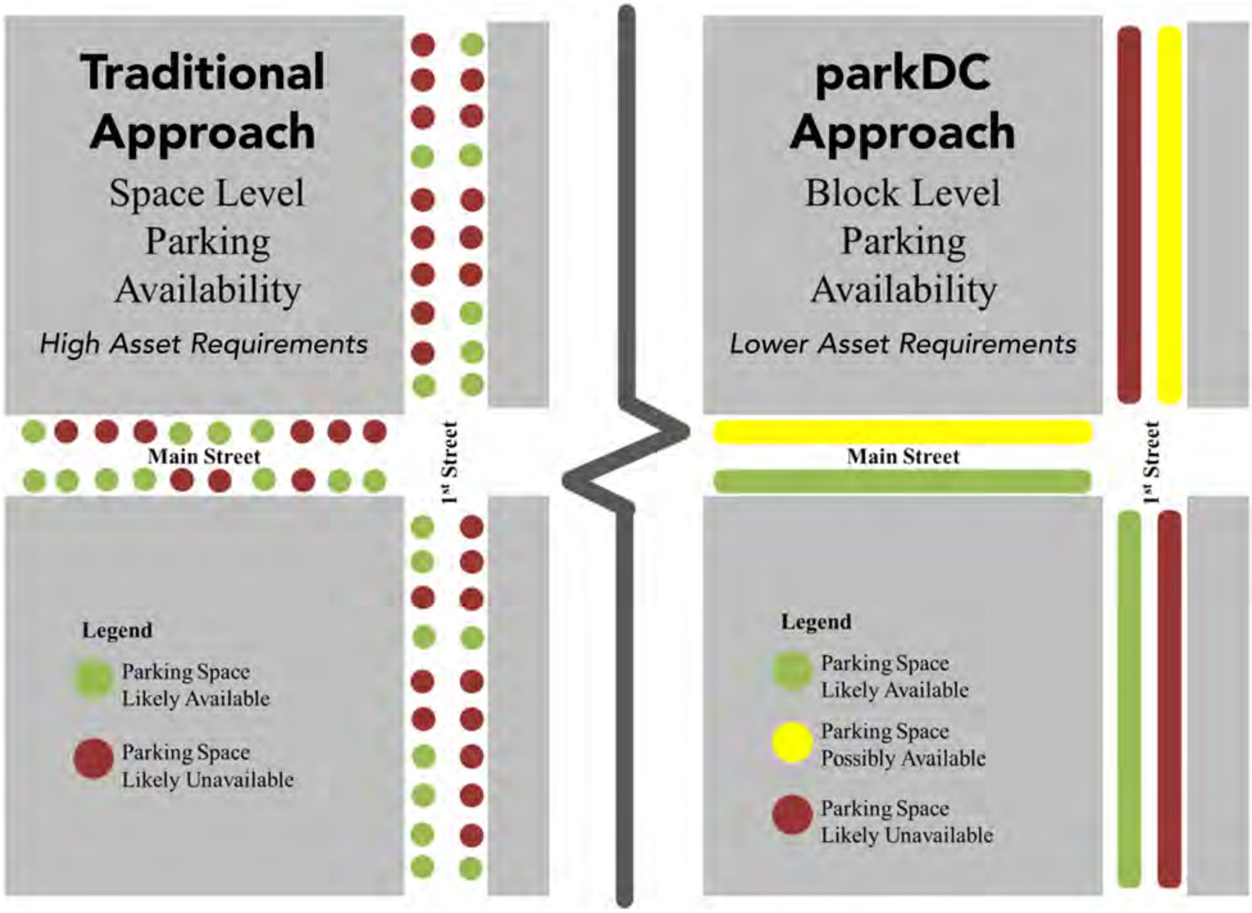
Figure 3-3. Space Demarcation Pole

Figure 3-4. Outreach materials for conversion to pay-by-space from pay-and-display

3.4 STEP 2: SYSTEM DESIGN

DDOT's asset-lite approach questions how thorough data needs to be to make reasonable predictions about occupancy. By understanding the purpose behind collecting occupancy information, DDOT could adjust the level of detail needed, resulting in a more cost-efficient, flexible system. To this end, DDOT decided to report parking availability by block rather than by space. By providing data on the likelihood of finding a space at the block level—which is good enough for a driver searching for an available parking space—DDOT reduced the accuracy requirement and consequently the number of assets needed. Figure 3-5 illustrates this concept.

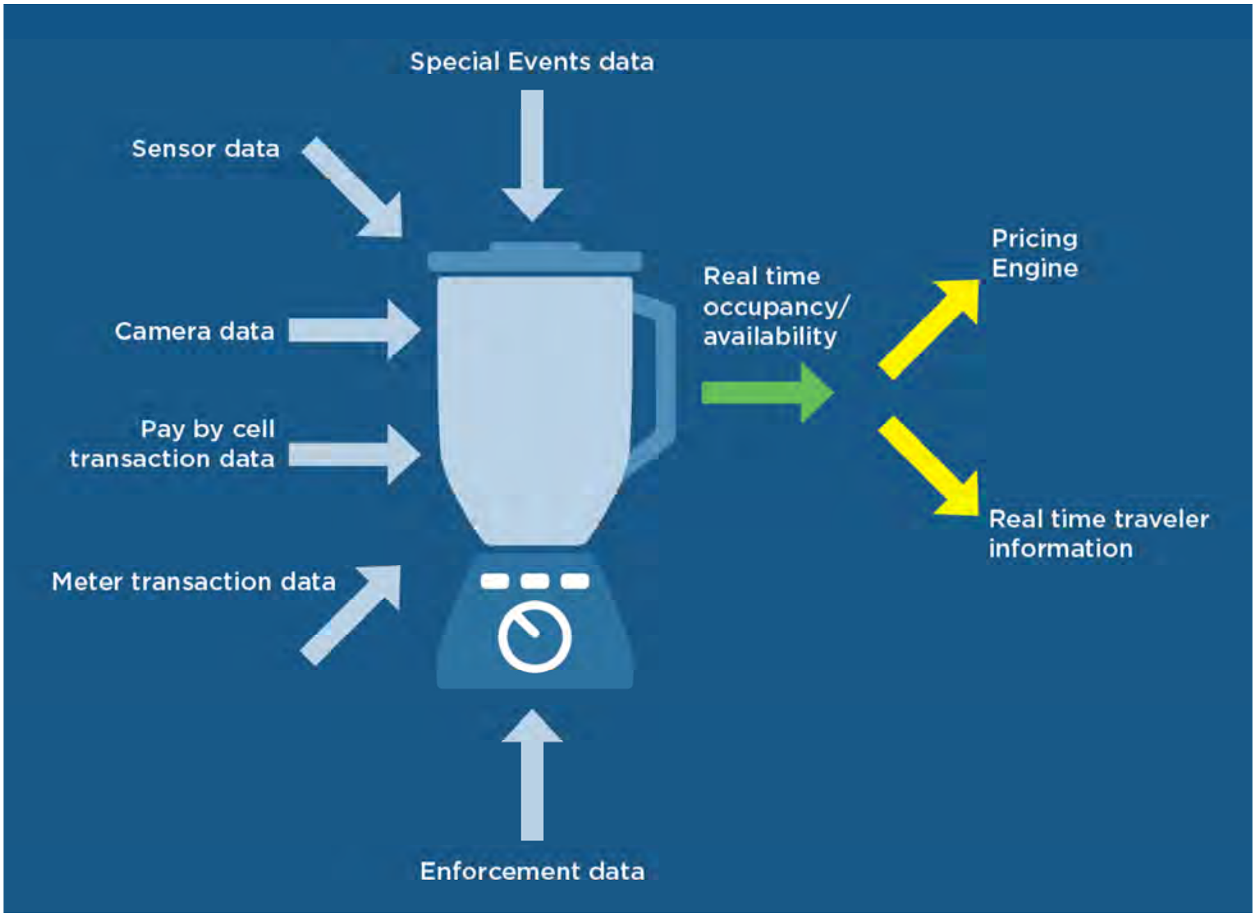
Figure 3-5. Block-level probabilities compared to space-level availability



3.5 STEP 3: DATA FUSION

The final step in the step-down approach helps DDOT meet the goal of the asset-lite approach: reducing the number of data collection devices that must be deployed by combining data from multiple sources. DDOT tested a variety of data sources to determine the optimal mix to predict real-time parking occupancy and inform both the pricing engine and real-time traveler information system for the pilot (Figure 3-6). By establishing which technologies performed best under various conditions and blending data from a variety of sources, DDOT was able to develop relationships and proxies, lowering costs and improving accuracy. More information on occupancy data and the data fusion methodology are found in the next two sections.

Figure 3-6. DDOT's mix of real-time and historic data sources



3.5.1 Data Fusion Approach

DDOT has worked to develop reliable occupancy data from multiple components of the parking ecosystem, including payments at networked parking meters, pay-by-cell transactions, temporal and spatial occupancy sampling, and parking citations. By leveraging a variety of data sources, DDOT can either supplement or supplant meter payment and sensor data to paint a picture of occupancy that allows for accurate rate recommendations and helps motorists find parking.

The data fusion approach relies on other data sources as stand-ins (data proxies) for the spaces without in-ground sensors and data analytics to predict occupancy. Here is how it works:

Phase I: Strategic Sensor Deployment

Temporal data collected using portable closed-circuit television (CCTV) cameras, time-lapse cameras, meter transactions and pay-by-cell transactions helped identify occupancy characteristics of on-street parking spaces by time of day and day of week. This information was used to develop a sensor deployment strategy that can provide highly-accurate real-time occupancy information about the whole pilot area. The pilot started with an assumed 50% sensor coverage.

Phase II: Refining Occupancy Information Derived from Sensors Using Data Fusion

DDOT's pay-by-space configuration paved the way to improve data collection and accuracy, making data fusion possible. The occupancy estimates from Phase I were combined with real-time data from other parts of the parking ecosystem to derive more refined and accurate occupancy estimates. The predictions were fine-tuned through an iterative, continuous process.

Phase III: Finding the Minimal Viable Sensor Coverage

During Phase III, DDOT ignored certain components of data to determine if they could accurately predict occupancy without them. DDOT found that the 50% sensor coverage established in Phase I provided the minimum viable coverage for the pilot area. No changes were made to the original pilot sensor deployment.

The results of the data fusion approach are discussed below.

3.5.1.1 PHASE I - STRATEGIC SENSOR DEPLOYMENT

Strategic sensor placement was key to the success of parkDC's asset-lite approach. DDOT used the following guidelines to ensure the best possible placement for the pilot sensors:

- **Determine the acceptable level of detail.** The occupancy estimates are utilized for two purposes:
    - Developing the pricing strategy
    - Informing the real-time parking availability app

  Of the two uses, traveler information requires a higher level of data accuracy because if the public does not trust that they will receive good information, they could potentially lose faith in the information provided. If travelers do not use the information provided, it cannot help alter behavior.

  As highlighted in Step 2 of the asset-lite approach, the requirements for accurate traveler information can be reduced by efficient interface design. Providing customers with block-level probabilities reduces the need for data about every individual parking stall.

- **Apply spatial and temporal sampling to gather high-quality occupancy data at reduced cost.** In spatial sampling, sensors or other detection devices are installed in only a fraction of the available spaces. Using models of spatial dependence (the tendency for nearby locations to influence each other and to possess similar attributes) at different locations, DDOT can calculate the expected error in occupancy predictions for any given sensor arrangement. DDOT used an algorithm to pick the sensor arrangement that best minimizes errors.

- **Test multiple sensor vendors to ascertain the best vendor for the District.** DDOT performed a technology assessment of two different sensor vendors. After determining both were acceptable, the pilot area parking spaces were divided between the two vendors using clustering algorithms to minimize communications infrastructure duplication.

The rest of this section provides more details of how DDOT used the guidance above to deploy the sensors using the following three steps:

Initial Sensor Testing → **Temporal Sampling** → **Sensor Deployment Algorithm**

3.5.1.1.1 Initial Sensor Testing

The pilot began by gathering data from seven block faces in the pilot area with 100% in-ground sensor coverage to test the sensors and to model and evaluate the effectiveness of sampling methods (Figure 3-7). A total of 50 in-ground sensors from two different vendors were assessed. Dome mounted sensors were also tested on five block faces in the pilot area. Outliers, such as known holidays, street closures, and special events, were removed and occupancy estimated using a fraction of the data. Those estimates were then compared to actual occupancy collected from portable CCTV cameras to determine accuracy. Through this process, DDOT verified that:

- Parking use in two spaces on the same side of a block is more likely to be similar than two spaces across the street from each other
- Occupancy in two spaces across the street from each other correlate more than two spaces on different block faces, despite the spaces being the same distance from each other

This finding is demonstrated in Figure 3-8 below. Because of this assessment, DDOT assumed that occupancy should be determined by block using data from that block. Space-level patterns helped DDOT identify strategic “indicator spaces” that provided a stronger indication of block-level occupancy than other spaces on their associated block faces.

Figure 3-7. Sensor installation locations for early sensor test

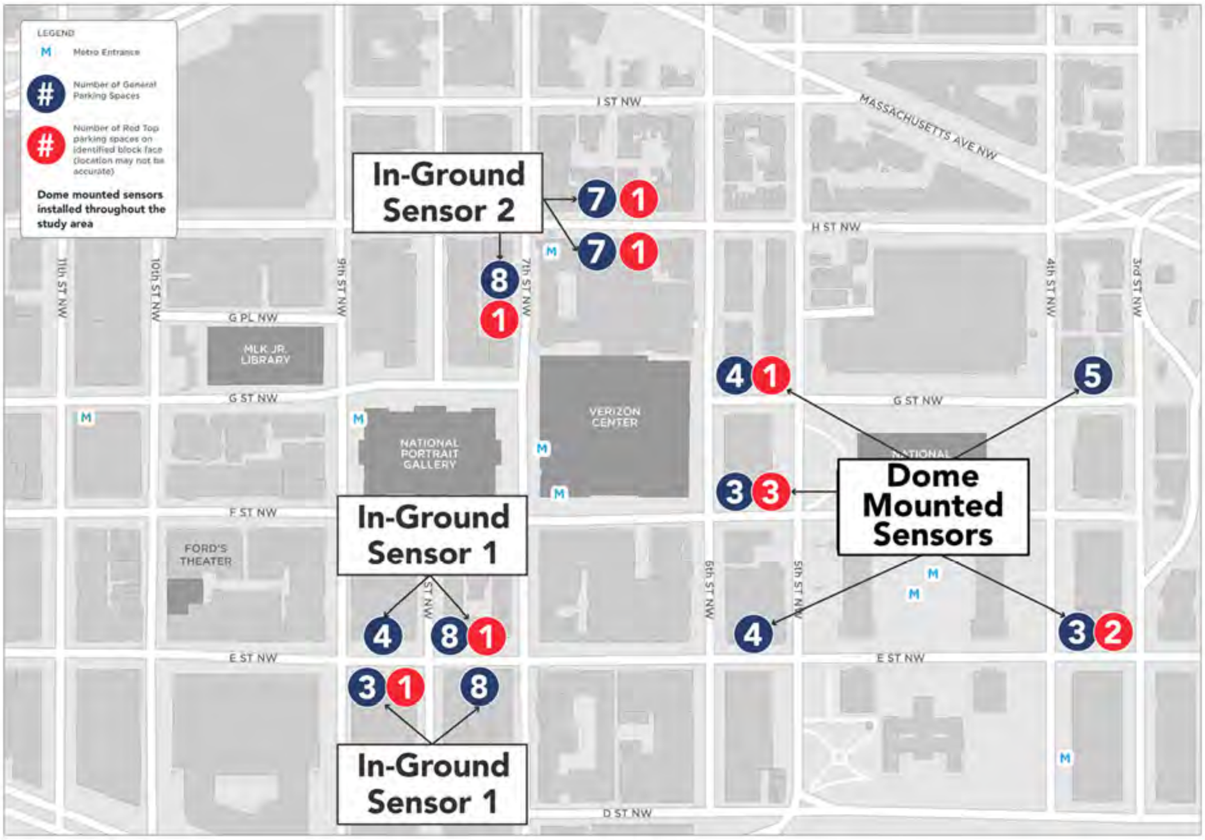
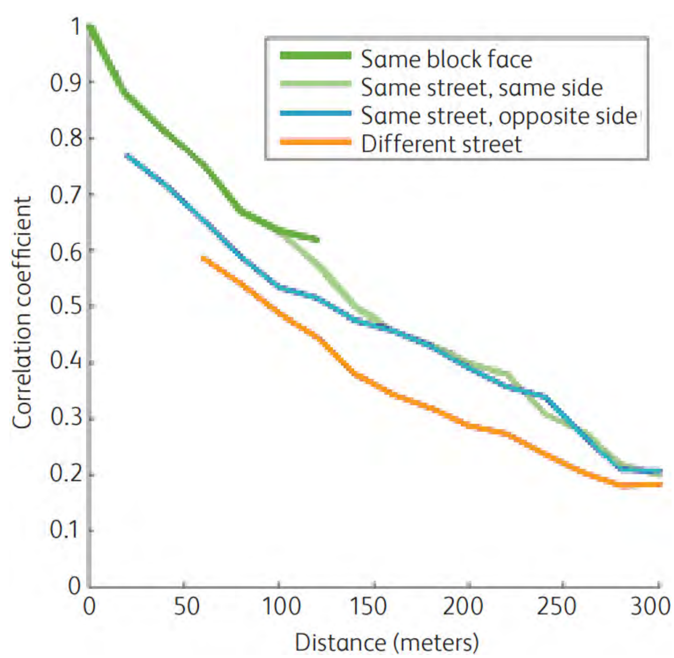


Figure 3-8. The spatial correlation between occupancy for pairs of stalls at different distances and with different relationships

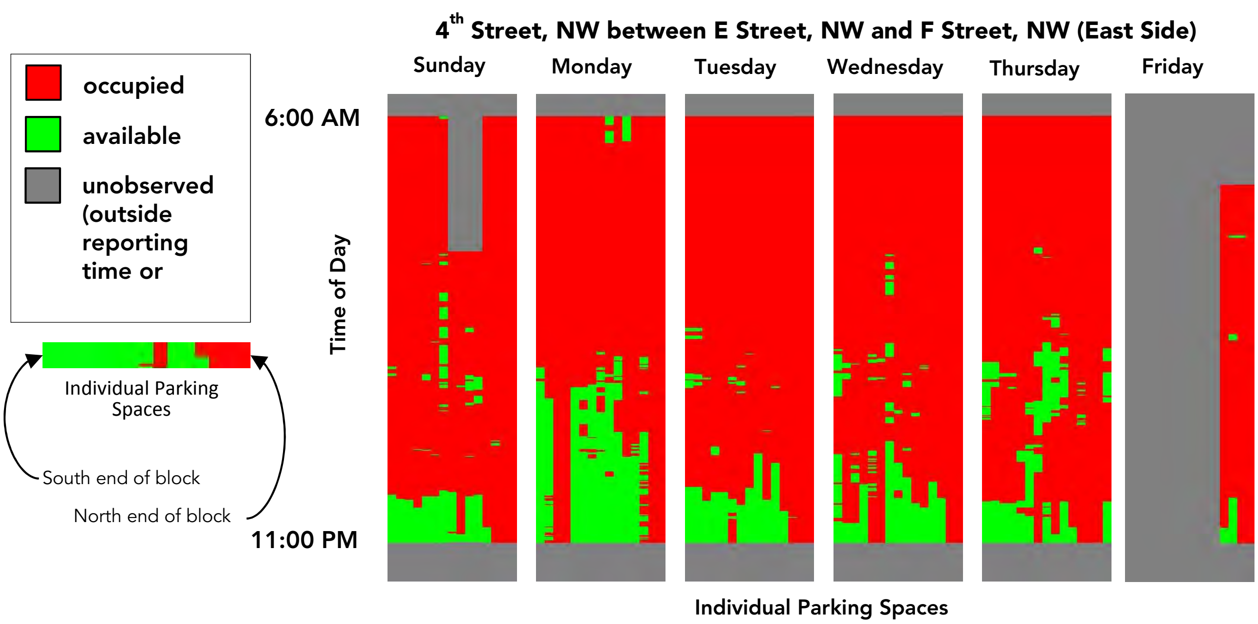


3.5.1.1.2 Temporal Sampling

To help determine the right location for each sensor, DDOT used temporal sampling from portable CCTV cameras analyzed with computer vision algorithms. Temporal sampling, or observing blocks during different periods, assumes that a block's past performance can help accurately predict future performance. 58 blocks were observed for a week each over 13 weeks using six mobile camera trailers. Data collection was prioritized on blocks at both the low and high extremes of paid usage, and blocks with large variations of paid usage. An example of the results of these observations are shown in Figure 3-9. As shown, red indicates spaces that are occupied, green indicates spaces that are available, and gray indicates unobserved usage, either due to being outside data reporting times (between 11:00 p.m. and 6:00 a.m.), or due to sensor communication issues.

Based on the assumption that occupancy can be determined by block using data from that block or immediately adjacent blocks, the CCTV data collection helped determine occupancy values for every parking stall in the pilot area. Groups of spaces on each block were examined to verify those that best represented the average occupancy on the block. This pilot led to the conclusion that DDOT could accurately predict occupancy on a block by placing fewer sensors on larger blocks with more curbside parking spaces and more sensors on blocks with fewer spaces.

Figure 3-9. CCTV results at a sample block face (right)

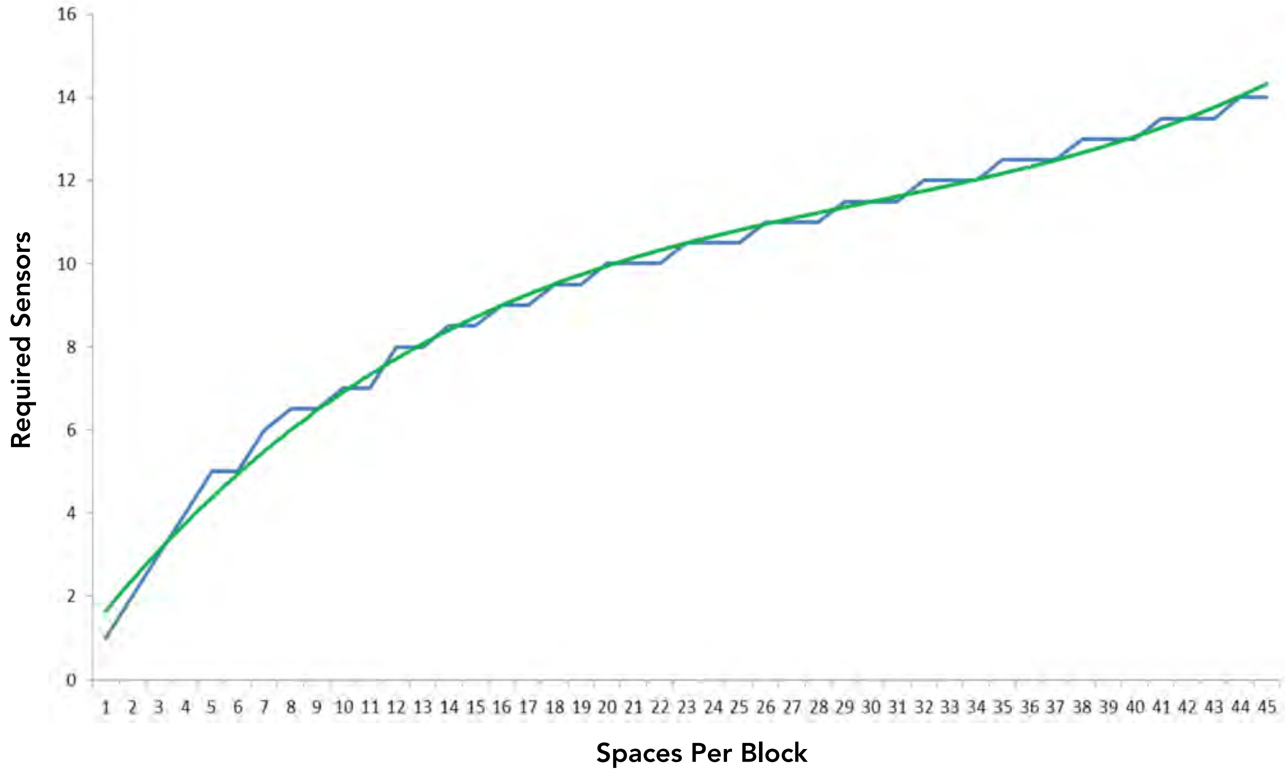


3.5.1.1.3 Sensor Deployment Algorithm

DDOT's sensor deployment algorithm ensured that the appropriate number of sensors was allocated on each block face to ensure the needed level of accuracy (Figure 3-10). DDOT also compared the fraction of occupancy during periods of high demand (greater than 90%) to low demand (less than 70%) and allocated additional sensors to those blocks where the difference was highest. The number of stalls requiring sensors were generally reduced when payments closely correlated to occupancy. In addition, sensors were also allocated to cover all eighteen Red Top Meters (meters reserved for persons with disabilities) in the pilot area.

There are 252 different ways to install five sensors in 10 stalls, and a huge number (close to a centillion) ways to install 450 sensors in 900 spaces.

Figure 3-10. Sensor deployment algorithm



General business rules for the sensor deployment included:

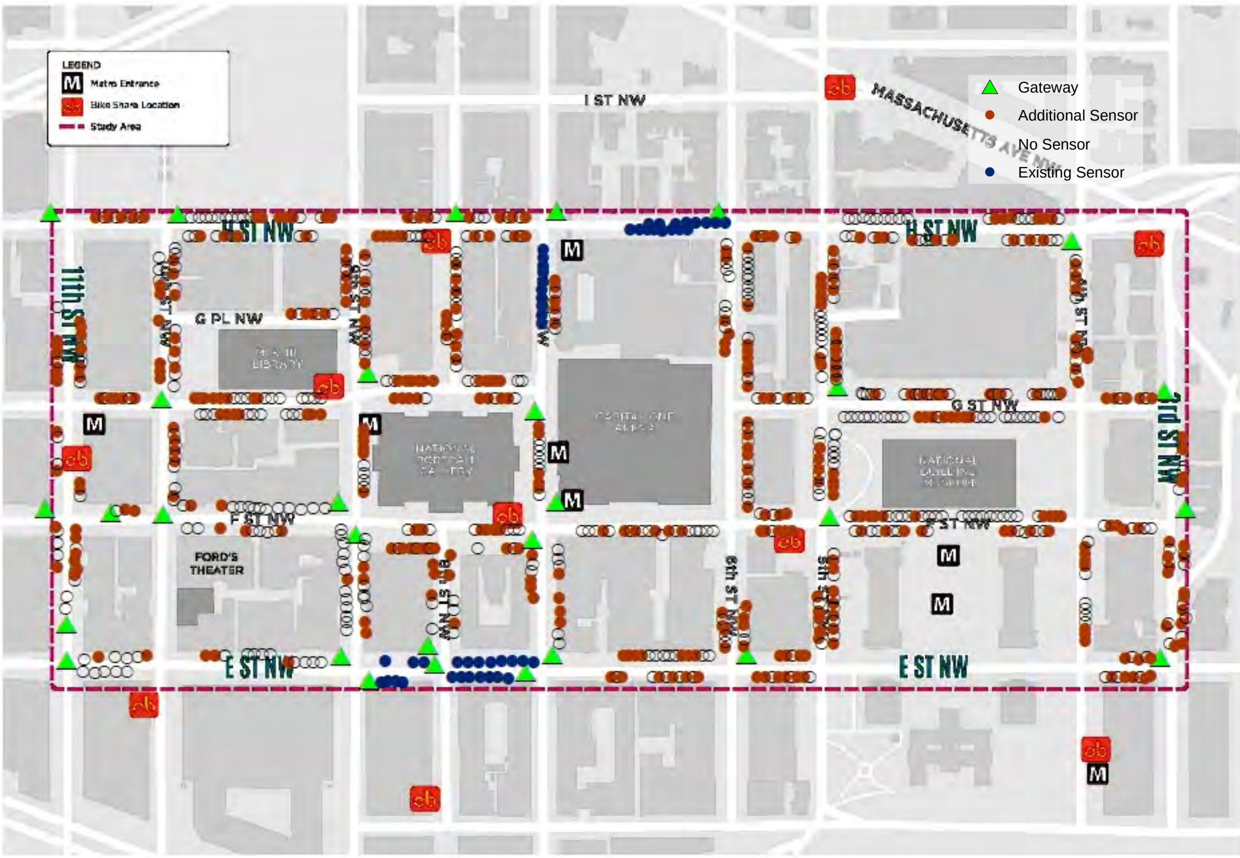
- Blocks with fewer spaces require a higher percentage of sensors
- Blocks with greater congestion require more sensors than blocks with fewer parkers
- Sensors are placed to maximize spatial coverage
- Percentage of coverage on a block depends on variability between spaces and on variability from day to day

After initially testing 50 sensors, DDOT procured another 450 sensors for an overall 50% sensor coverage in the pilot area.

DDOT sought to reduce the need for communications infrastructure and the related costs associated with the 450 new sensors and allocated sensors using clustering algorithms which grouped sensors from each individual vendor together. This methodology effectively minimized the distances between existing and new sensor installations. By accounting for existing sensors as well as the locations of wireless communications infrastructure in the final deployment strategy, DDOT required fewer antennae and reduced costs.

DDOT produced mapping files for the installation as represented in Figure 3-11 and made minor changes during the installation process as required by construction and the occasional parking meter relocation.

Figure 3-11 Sensor Installation Map for Pilot Area



3.5.1.2 PHASE II: REFINING OCCUPANCY INFORMATION DERIVED FROM SENSORS USING DATA FUSION

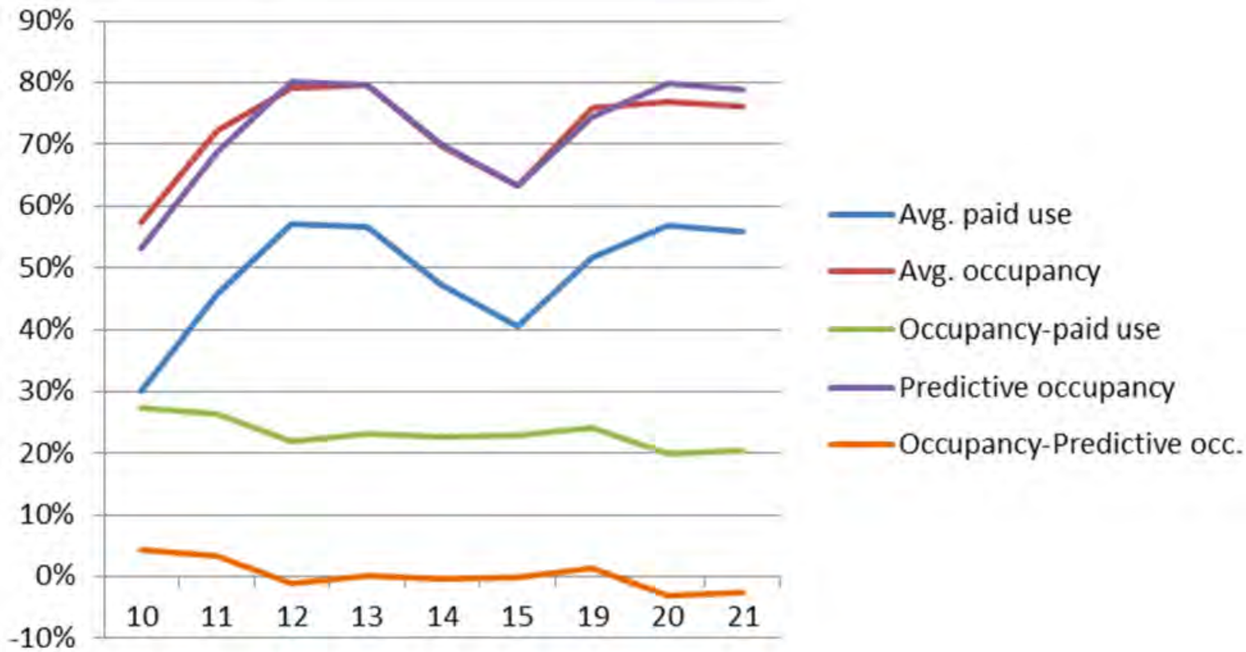
Spatial sampling on blocks with partial sensor coverage and temporal sampling at locations with minimum or no sensor coverage provide opportunities to further enhance predictive algorithms with the goal of fusing different data sources to estimate occupancy distributions. There are challenges associated with fusing data with different levels of coverage, speed of transmittal, and detail. However, when successfully done, it can improve occupancy estimates.

3.5.1.2.1 Increasing Accuracy of Predictions through Data Fusion

Figure 3-12 represents just how disparate data sources can be on a sample block. Paid use (the blue line), or the fraction of total time available for purchase across all spaces on a block that has been purchased, does not line up with actual occupancy captured via full sensor coverage and/or Portable CCTV cameras (the red line). By studying the difference between these values, DDOT was able to create a predictive factor (green line) that could be added back to real-time payments to predict occupancy (purple line). Using this technique DDOT found that the error in estimating the average occupancy at a given time-of-the-week is relatively low at 6.3% across the pilot area, and even lower (5.7%) on the block in question.

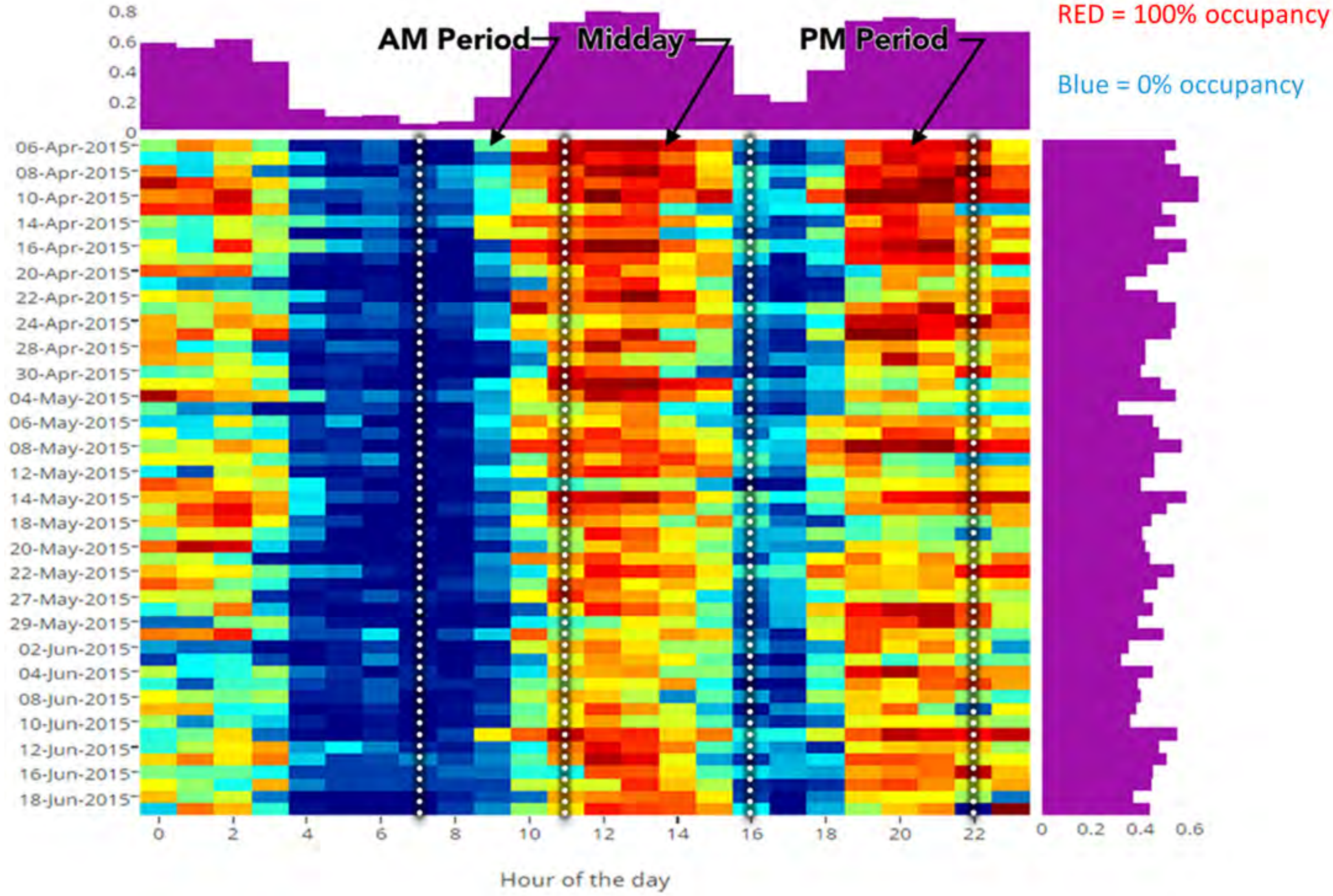
This analysis, however, fails to capture the true impact of illegal (unpaid) parking. Motorists illegally parking without paying negatively impact the relationship between paid use and occupancy. Historical parking citation data can help round out the picture. Each time a parking enforcement officer issues a citation for an expired meter, that citation represents an unpaid parker. By factoring illegal parkers into average paid use, DDOT achieved an even lower error of only 5.8% in the entire pilot area.

Figure 3-12. Predicting occupancy using historical payments



With the addition of sampled sensor data to payment and camera data, DDOT can make precise predictions for each block every minute of the day, every day of the week. Output from the sensors and cameras uncovers trends by space and by block, providing real data instead of anecdotes about parking and space use. Figure 3-13 provides an example of the analysis output, revealing critical information about hourly and daily use. Hourly use is demonstrated by the purple histogram on the top of the figure. Daily use is documented in the purple histogram at the right side of the figure.

Figure 3-13. Sample occupancy output from data fusion approach for one block face



3.5.1.3 PHASE III: FINDING THE MINIMAL VIABLE SENSOR COVERAGE

Building on Phases I and II, DDOT further merged spatial and temporal data to see if even greater reductions in sensor coverage would yield comparable results in the pilot area. For this pilot, the original 50% sensor coverage was deemed appropriate. DDOT plans to regularly revisit this Phase III assessment for this area and before deployment in other areas of the District. The constantly changing parking landscape requires ongoing refinement of occupancy predictions. Businesses come and go, sensors fail or are removed, events change parking patterns, and new technologies arise. Phase III bookends an iterative, nimble approach to evolving technology deployment, improving user-friendliness for system users and policymakers.

3.5.2 Technologies Used to Collect Occupancy Data

As part of the third step in the step-down approach, DDOT attempted to work out the best methodology for capturing high-quality occupancy data in the pilot area. The traditional method of collecting parking occupancy information is to count the number of vehicles parked on a block manually. Data collected in this manner is labor intensive, unreliable, not timely or scalable, and can require significant post-processing data reduction. While DDOT has used manual data collection via mobile devices in neighborhood parking studies, this approach was deemed insufficient for the pilot. Instead, DDOT used manual data collection only for periodic validation of other methods and of the results of the data fusion process.

In searching for a better occupancy detection and prediction solution, DDOT conducted a thorough and wide-ranging technology assessment for on-street parking occupancy sensing. The technology assessment evaluated the feasibility of each technology in the District environment. The on-street occupancy detection technologies known to be available to DDOT at the outset are summarized in Table 3-1. *Further details on DDOT's hunt for the best occupancy detection technologies can be found in the Data Book.*

Table 3-1. Summary of Occupancy Detection Technology

Type of Methods to Detect Parking Occupancy	Advantages	Disadvantages	Deployed in parkDC Pilot?
In-Ground Sensors	▪ Can accurately detect vehicles ▪ Data available in real time	▪ High installation and maintenance costs ▪ Coordination needed with capital and maintenance projects, development projects, and snow removal operations ▪ Detection algorithms need to be adjusted to account for urban noise such as underground utilities, subways, and buses on curb lanes ▪ May not detect vehicles accurately in poor weather conditions (standing water, snow cover) ▪ Not portable; must be permanently installed in the ground ▪ Require demarcated spaces. Pilots in undemarcated areas have been unsuccessful	▪ Yes – 500 sensors were deployed over 1,000 metered spaces on 92 block faces, and 18 sensors were deployed at Red Top parking meters (reserved for persons with disabilities)
Dome-Mounted Sensors	▪ Can accurately detect vehicles ▪ Can be networked using same system as networked meters ▪ Can leverage assets	▪ May impact meter battery life ▪ May require changes to infrastructure (yoke redesign) ▪ Not portable; must be	▪ Yes – dome mounted sensors were installed to test technology but not ultimately used in the pilot

Type of Methods to Detect Parking Occupancy	Advantages	Disadvantages	Deployed in parkDC Pilot?
	already in place ▪ Data available in real time	installed within existing single-space meters ▪ Requires installation and maintenance costs ▪ Only work with single-space meter deployments; cannot use with multi-space meters	
Portable CCTV	▪ Measures space between cars and vehicle lengths ▪ Portable ▪ Potential to also provide vehicle classification and data from proximate travel lanes, including vehicle counts, vehicle speeds, bicycle, and pedestrian counts ▪ Spaces do not need to be demarcated	▪ High installation and maintenance costs ▪ May be prone to vandalism ▪ Moving and placing cameras can be difficult ▪ Privacy concerns ▪ Data reduction required, via algorithms that can detect cars or staff to review video. ▪ Shorter battery life than sensors ▪ Data may not be available in real time if data is stored locally	▪ Yes – six portable trailers featuring up to four cameras each provided data for 58 blocks at the outset of the pilot
Time-Lapse Cameras	▪ Cheaper, commercially available product Long battery life ▪ Portable ▪ Relatively small size ▪ Potential to also provide vehicle classification and double parking in nearby travel lanes	▪ Data is not available in real time ▪ Moving cameras can be difficult and require location for mounting ▪ Privacy concerns ▪ Data reduction required via algorithms that can detect cars or staff to review video.	▪ Yes – 15 time-lapse cameras deployed at loading zones in the pilot area for periodic monitoring
Fixed Camera	▪ Automated data reduction ▪ Measures space between cars and vehicle lengths ▪ Potential to also provide vehicle classification and data from proximate travel lanes, including vehicle counts, vehicle speeds, bicycle, and pedestrian counts	▪ Not portable ▪ Privacy concerns ▪ Requires accurate computer vision algorithms ▪ Requires data management, installation and maintenance costs	▪ Yes – Fixed cameras on 2 block faces to test technology

Type of Methods to Detect Parking Occupancy	Advantages	Disadvantages	Deployed in parkDC Pilot?
	▪ Spaces do not need to be demarcated		
Cameras with GPS	▪ Cheaper, commercially available product easily installed on a motor vehicle	▪ Data is not available in real time ▪ Privacy concerns ▪ Requires staff time to review, set up driving routes, and review video ▪ Urban canyon effect can hinder GPS data, GPS accuracy	▪ No
Manual Counts	▪ No need to invest in technology	▪ Accuracy is hard to verify ▪ Data is not available in real time ▪ Requires significant labor; generally, requires more labor costs than any other method	▪ Yes – manual counts conducted on 14 block faces in the pilot area and 10 block faces in a control area before and after pilot implementation
Payment and Citation Data	▪ Data available in real time	▪ Does not account for turnover, length of stay, exempt parkers, or illegal parkers ▪ Payment and citation data not always a good proxy for occupancy ▪ Requires data management costs	▪ Yes – payments from networked multi-space meters, single-space meters, and pay-by-cell mobile application specific to 900 spaces, including 92 Red Top meters

Type of Methods to Detect Parking Occupancy	Advantages	Disadvantages	Deployed in parkDC Pilot?
License Plate Recognition Technology	▪ Automated data reduction ▪ Can detect vehicle plate numbers and be used for enforcement purposes	▪ Cameras are not able to differentiate between vehicles that are parked versus in transit ▪ Data is not available in real time ▪ Requires data management, installation and maintenance costs ▪ Requires staff to either drive vehicles or needs to be mounted on fleet vehicles that circulate regularly ▪ The cameras do not distinguish areas of the block where curbside regulations change. Routes need to be constructed to address this. ▪ Urban canyon effect can hinder GPS data, GPS accuracy	▪ No
Crowdsourcing Applications (e.g. ratings of available parking on a block or in a zone)	▪ No or minimal assets (e.g. signage) to install in the field ▪ Data available in real time	▪ Data may be incomplete ▪ May require contracts and some staffing for data integration ▪ Need to engage with various app developers to either develop a crowdsourcing application or use their data to integrate with other data the agency obtains. ▪ Users must agree to share their location information to get complete data	▪ No

The following sections describe the data collection technologies selected for use in the pilot. They introduce the technology, explain how it works, and outline how the technology was used in the pilot.

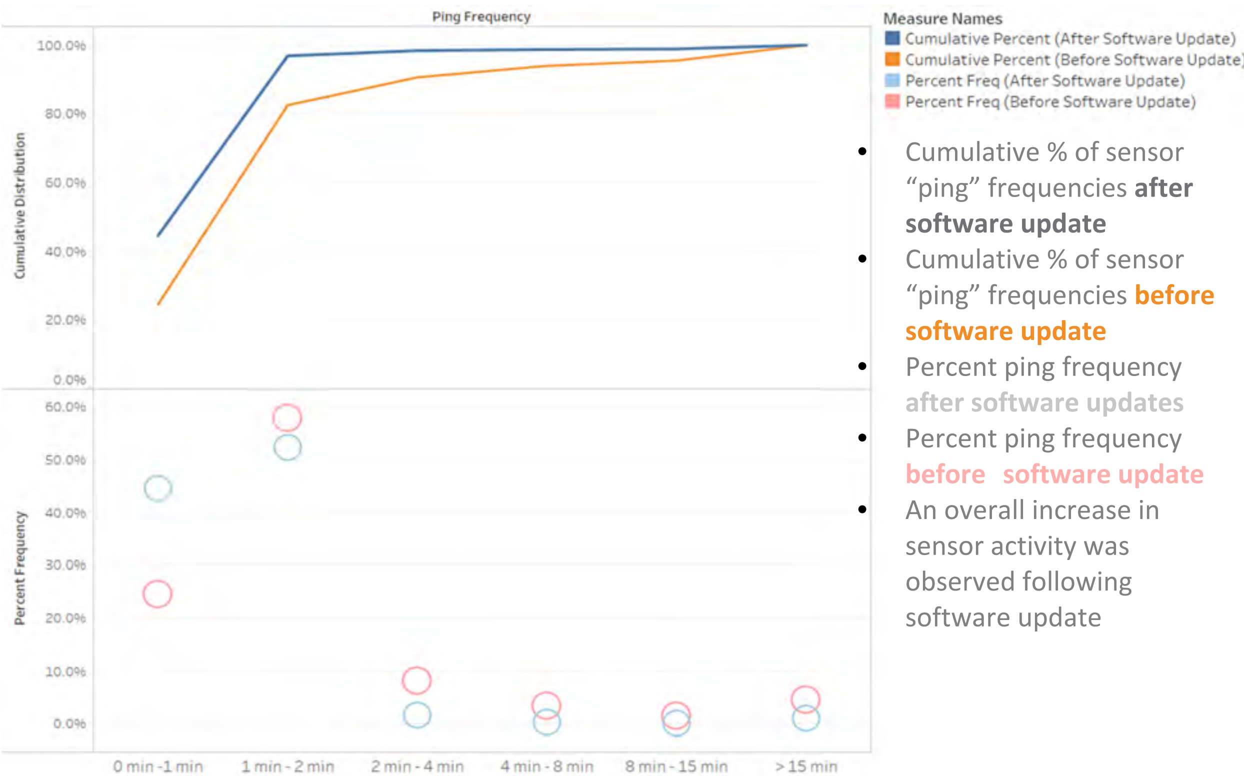
3.5.2.1 IN-GROUND SENSORS

Parking sensors about the size and shape of a hockey puck are placed in the pavement to automatically collect parking occupancy data using magnetometers, radar, and/or optical readers. These sensors wirelessly transmit data to nearby networked communication equipment. DDOT initially selected two sensor vendors to provide occupancy data for the pilot. Two vendors allowed DDOT to test multiple iterations of the same technology and find the best product for the pilot.

In an urban environment, fixed objects such as utility boxes and signal cabinets, as well as moving items such as underground heavy rail transit vehicles, cause interference with the sensors' magnetometers. This can reduce their ability to accurately detect occupancy. While vendors have developed strategies to counter this interference, the varying nature of blocks in urban environments still poses challenges for sensors. The use of cameras and manual field verification can help test the accuracy of the parking sensors.

Early in the process, DDOT worked with sensor vendors to identify sensor communication issues. The sensor vendors used a "heartbeat" report which showed the number of times a sensor pinged a back-office connection. The sensors with the lower number of pings were troubleshot until their ping frequency rose. Figure 3-14 shows how the number of sensors pinging at an acceptable level rose sharply after a software update.

Figure 3-14. Sensor ping frequency and cumulative number of sensors reporting at acceptable frequency intervals



- Cumulative % of sensor "ping" frequencies **after software update**
- Cumulative % of sensor "ping" frequencies **before software update**
- Percent ping frequency **after software updates**
- Percent ping frequency **before software update**
- An overall increase in sensor activity was observed following software update

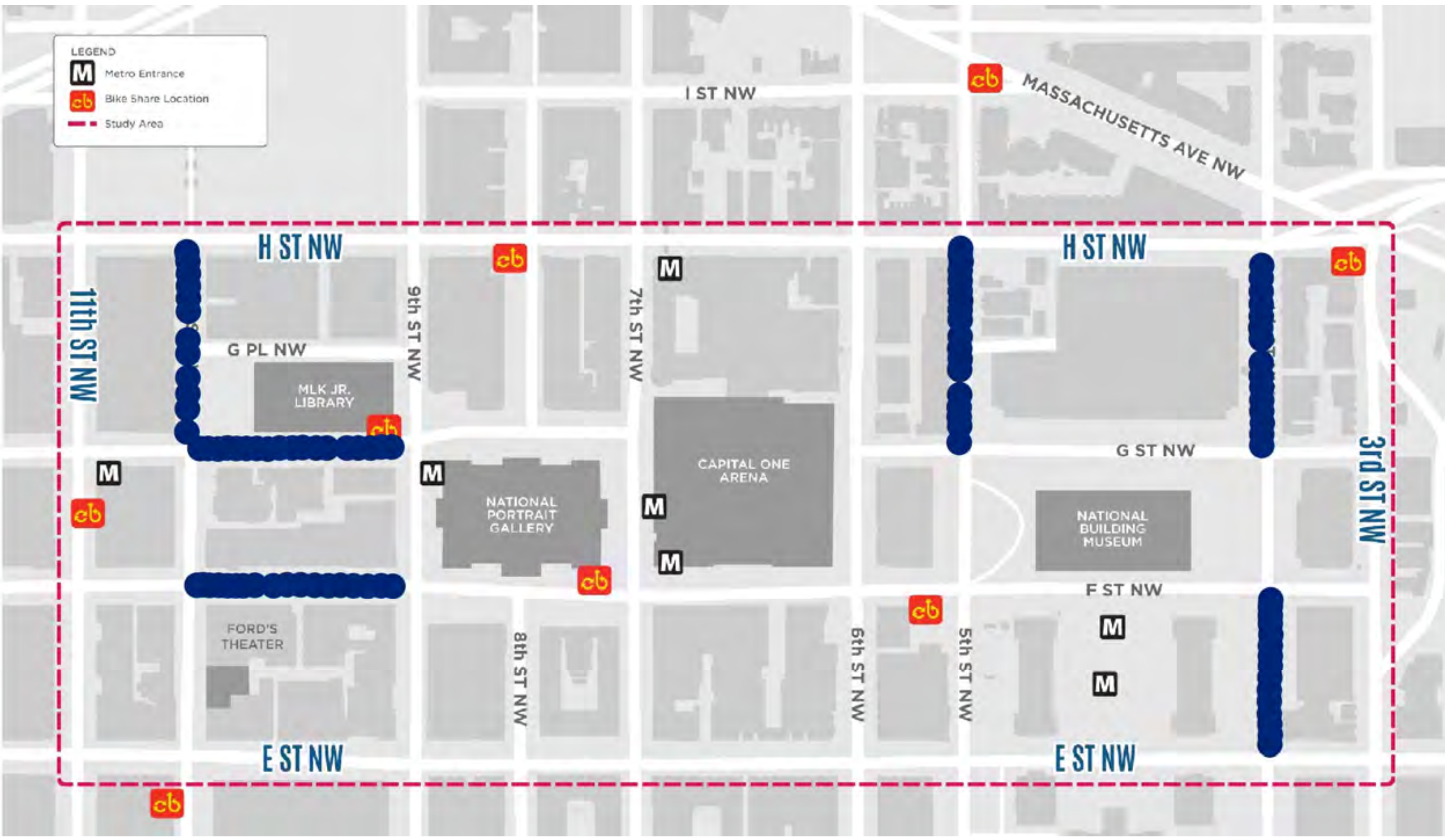
3.5.2.2 PORTABLE CCTV CAMERAS

Portable CCTV cameras gather detailed camera footage that can measure space between cars and vehicle lengths and provide vehicle counts, vehicle speeds, vehicle classification, and bicycle and pedestrian counts. CCTV cameras are transported on trailers and accrue high installation and maintenance costs. Technicians can process video footage in two ways: manually (requires staff time) or automatically (requires automation using algorithms that can detect cars).

DDOT used portable CCTV cameras with automatic data processing in the pilot to lay the foundation for in-ground sensor deployment. A block-by-block review of the pilot area was completed to identify blocks appropriate and inappropriate for portable cameras. Six trailers with cameras were moved on a weekly basis throughout the pilot area (four weeks of coverage shown in Figure 3-15), capturing information from 58 blocks. Because single cameras did not cover many spaces, up to four cameras were mounted on each trailer. Unlike in-ground sensors, the CCTV disrupted curbside space in the pilot area. Each trailer was about the size of a compact car (12.5 ft long, 7 ft wide, and 8-30 ft high depending on whether cameras were extended or retracted). Moving the trailers was extremely labor intensive, requiring several hours a week per trailer.

DDOT developed a methodology to guide installation of mobile CCTV trailers to optimize accuracy. It was imperative for operators to set up the cameras properly per vendor guidelines to ensure data capture and analysis using computer vision. Obstructions, like large vehicles and trees, can impact the accuracy of the counts and were factored into the analysis. During installation, DDOT attempted to minimize these obstructions. The computer vision algorithms were modified to address potential camera shake due to wind or the passage of large vehicles. This required the algorithms to be individually fine-tuned for each installation. Each installation also required setup and output generation reviews as well as algorithm testing and processing.

Figure 3-15. One week of portable CCTV coverage



Data was infrequently captured outside of operable meter hours to preserve battery life, and the trailers required frequent data transfers locally using flash drives. Because of law enforcement concerns, there were several blocks where cameras were off limits.

The occupancy analysis used minute-by-minute images run through an automated software system. While that painted an accurate picture of use, it did not provide enough detail about turnover, as vehicles leaving and arriving at a space in the same minute were not necessarily captured. Furthermore, the arrival or departure of two vehicles was interpreted as a single, large vehicle event on a couple of occasions. To assess accuracy, the camera images were manually reviewed at set five-minute intervals to ensure the analytic software used to measure occupancy and turnover was accurately estimating both.

3.5.2.3 TIME-LAPSE CAMERAS

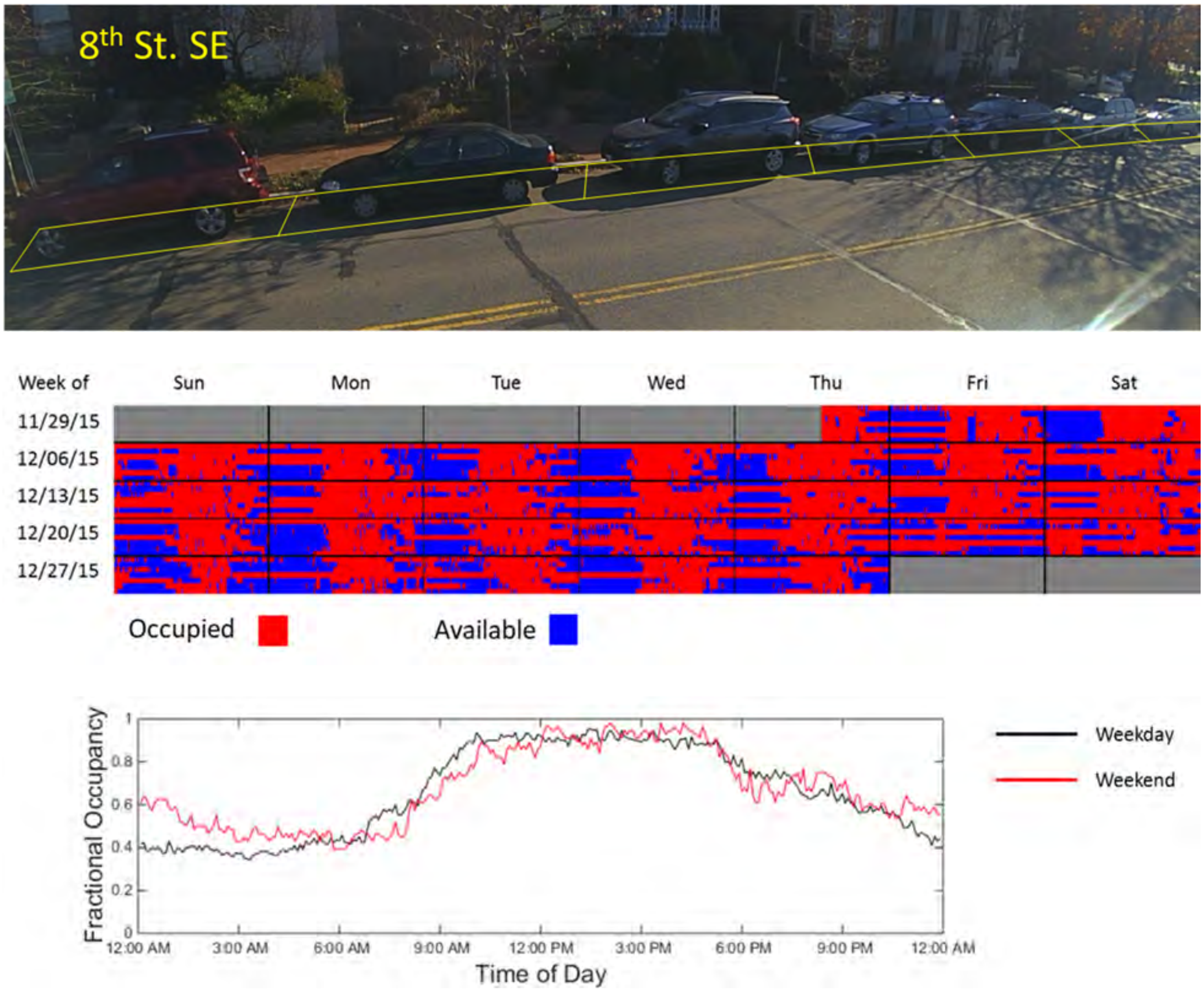
DDOT used time-lapse photography to monitor parking, occupancy, and turnover. This approach uses readily available off-the-shelf technology, shown in (Figure 3-16) and provides more robust and detailed data over a longer duration than portable CCTV cameras. Time-lapse cameras can be mounted on city assets, such as streetlight or signal poles by a technician. When set to take photos every five minutes, these cameras can remain in the field for over a month with two AA batteries.

Figure 3-16. Time-Lapse Camera

There are two generally accepted techniques for analyzing time-lapse photography footage. The first is to review the footage manually, which is time consuming and potentially expensive depending on labor rates. The second is to review it using computer vision. Video analytics, as demonstrated in Figure 3-17, provide insights regarding space occupancy and availability.

DDOT has used time-lapse cameras for a range of parking studies, but in the pilot used them specifically for observing loading zone activity. DDOT charted occupancy patterns by vehicle type on weekdays and weekends and used time-lapse photography to hone in on loading zone use and misuse in the pilot area.

Figure 3-17. Screenshot of time-lapse footage set up for data analysis (top), parking occupancy measured from time-lapse camera (middle), parking occupancy by time of day measured from time-lapse camera (bottom)



3.5.2.4 FIXED CAMERAS

DDOT tested fixed cameras as another potential source of real-time occupancy data. Fixed cameras were mounted on existing light poles in the pilot area to detect and classify parked on-street vehicles in real time. The parking event data was then sent over a Wi-Fi network, aggregated in the cloud, and made available through a set of secured APIs.

DDOT tested cameras on two block faces in the pilot area. The biggest challenges to the use of the fixed cameras were identifying and setting up a Wi-Fi network for the selected area and performing parking detection from a lower mounting angle than is typical (~15 ft) due to the use of shorter ornamental light poles in the pilot area. The Wi-Fi network was provided by the Office of the Chief Technology Officer (OCTO) of the District of Columbia. Due to several mounting and location challenges, installation took significantly longer than planned. These challenges, however, led to two key product improvements:

1. The video sensors and lighting control nodes can now operate over cellular as well as Wi-Fi networks, so if Wi-Fi is not available, communication can continue.
2. The parking detection algorithms were modified to support a low pole mount and continue to detect parking even when occluded by passing vehicles.

The project also inspired a new API that supports aggregating spot-by-spot data to the block face level, so it can easily be displayed on parking navigation maps for citizens and visitors.

Due to the installation delays, the cameras were evaluated against other technologies in the final assessment, but their data did not directly inform the pilot's occupancy and pricing models.

3.5.2.5 PAYMENT AND CITATION DATA

Along with active occupancy data collection from sensors and cameras, DDOT incorporated additional passive data that could serve as a proxy for occupancy data: payment and citation data. DDOT used these passive sources to supplement parking occupancy detection technology and minimize the number of assets deployed in the field. DDOT collected space-level payment information by moving to the demarcated, pay-by-space environment, as described above.

Due to relatively low correlations between payment data and occupancy, District payment transaction data alone would be an insufficient proxy for occupancy on most blocks. Placard usage and free parking for government vehicles contribute to the poor correlation between payment data and real-time occupancy. Also, payment data may not truly reflect the duration of a stay or turnover. This is because payment at District meters, customers pay when they park for the planned duration of their stay. If a customer vacates a space before their payment window ends, then reported payment data loses its accuracy. Consequently, while payment data can reduce the demand for parking occupancy technology, it is currently unable to fully offset the need for parking occupancy technology.

In the District, the Department of Public Works (DPW) is primarily responsible for parking enforcement and manages citations issued. DPW enforcement officers issue citations to non-compliant vehicles via networked handhelds, which upload citation details to a central location. The transition to demarcated parking in the pilot area allowed DPW officers to link citations with specific parking spaces. Like payment data, citation data serves as a proxy for occupancy data. Historical citation issuance, along with payment data, was used to supplement occupancy predictions using temporal and spatial sampling.

3.5.2.6 MANUAL COUNTS

DDOT also conducted manual parking occupancy counts. Surveyors collected weekday parking occupancy data on 14 block faces in the pilot area and 10 block faces in a nearby control area before the first price change and after the fourth price change. Table 3-2 shows the manual occupancy data collection time bands. This data was primarily used to understand issues related to double parking and placard use in the pilot area, discussed in sections 3.9.1.1.3 and 3.9.1.2.1, respectively.

Table 3-2. Manual parking occupancy survey time bands

Morning Period 1	Morning Period 2	Midday Period 1	Midday Period 2	Evening Period 1	Evening Period 2
8:15–9:15 AM	9:45–10:45 AM	11:15 AM–12:15 PM	2:00–3:00 PM	4:30–5:30 PM	6:30–7:30 PM

3.6 THE PRICING ENGINE

DDOT used data collected through the asset-lite approach to inform the pricing engine and develop price change recommendations. The data fusion process was used to inform each of the five price changes that were implemented throughout the pilot period.

Noted economists such as Dr. Donald Shoup advise that 15% of the spaces on a block should always be available to ensure there is adequate turnover and to avoid discouraging parkers. That goal (85% or 90% occupancy), however, does not necessarily tell a complete story. While 85% or 90% could represent an even distribution of demand over the course of an hour or day, it likely does not. Using average demand to guide pricing decisions fails to recognize nuanced yet critical parking trends.

A better methodology, like the one undertaken by the District, is to compare periods when use is too high to periods when use is too low. DDOT used technique to compare the fraction of high use (> 90% occupancy) to the fraction of low use (< 70% occupancy). If the fraction of high use less the fraction of low equaled:

- Greater than 38%, then DDOT recommended rate increases
- Between 38% and -38%, then the DDOT recommended no change in the rate
- Less than -38%, then the DDOT recommended rate reductions

DDOT prioritized simplicity and local conditions when developing the initial rate structure, building on the District-wide base price for on-street parking ($2.30/hr.) and limiting the total number of initial prices to three price bands: $2.00/hr., $2.30/hr., and $2.75/hr. A more aggressive rate structure was considered (five price bands with $1.75/hr. on the low end and $3.00/hr. on the high end) and discarded for the initial price change to systematically determine the impacts of incremental change and avoid the perception of price gouging. In addition to developing the preliminary rate structure, DDOT developed business rules for the pilot to set clear limits on the rate structure adjustment and communication processes.

Since the implementation of the first change in October 2016, the number of price bands has increased incrementally in accordance with the business rules. Rates increased more aggressively during later rounds as the amount of a rate increase or decrease needed to be sizeable enough to impact behavior. Five price changes were implemented during the pilot. As of the fifth price change, the rate structure has grown to encompass nine price bands, ranging from $1.00/hr. to $5.50/hr. Table 3-3 shows how the pilot rate structure has evolved since the first price change.

Table 3-3. Penn Quarter/Chinatown Pricing Pilot rate structures

Price Change	Rate Structure (hourly rates)								
Baseline				$2.30					
Round 1 ***October 2016***			$2.00	$2.30	$2.75				
Round 2 ***February 2017***		$1.50	$2.00	$2.30	$2.75	$3.25			
Round 3 ***May 2017***	$1.00	$1.50	$2.00	$2.30	$2.75	$3.25	$4.00		
Round 4 ***August 2017***	$1.00	$1.50	$2.00	$2.30	$2.75	$3.25	$4.00	$4.75	
Round 5 ***November 2017***	$1.00	$1.50	$2.00	$2.30	$2.75	$3.25	$4.00	$4.75	$5.50

While data has served as the foundation for the time bands and price changes developed for the parkDC pilot, institutional knowledge of and sensitivity to the effects of the pilot on customers have also been taken into consideration. DDOT's conservative, data-driven approach to implementing rate changes in the pilot area serves as a model for expanding the pilot to other neighborhoods within the District.

3.6.1 Segmentation

Rates were partitioned across the hours of a day to optimize demand. DDOT's goal was to reduce the likelihood of pricing errors while keeping the structure simple. Rates need to be both easy to understand and to communicate to customers in order for drivers to incorporate pricing into their decision-making. When motorists do not know what to expect in terms of rates, they cannot effectively respond to pricing signals. When they arrive at a meter they will pay whatever is required to park to avoid the hassle of finding another spot and the rates will fail to impact driver behavior. DDOT wanted to avoid this scenario.

DDOT sought to implement just three or four partitions per day and, whenever possible, began and ended the partitions on the hour to avoid confusion. Partitions were also influenced by rush hour restrictions that impact parts of the pilot area (7 AM-9:30 AM and 4 PM-6:30 PM). It is much easier for customers to plan their trips when they know rates will increase at noon as opposed to, say, 12:13 PM. Further, DDOT treated weekdays and weekends separately to simplify messaging.

Occupancy data was used to assess parking patterns in the pilot area and determine time of day segments when different price changes could go into effect. Three weekday time of day segments (7 AM–11 AM, 11 AM–4 PM, 4 PM–10 PM) and one Saturday time of day segment (7 AM–10 PM) were identified based on observed parking behavior in the pilot area. The meters operating on Saturday needed just a single segment based on reduced weekend utilization.

3.6.2 Increments

The amount of an hourly rate increase or decrease must be sizeable enough to impact behavior. The business rules for the parking pilot stipulated that all rate adjustments would be made in increments of no less than 50 cents up or down. Smaller increments implemented in precedent demand-based parking pricing studies did not have large impacts on changes in parking behavior. The business rules also specified that rate changes would be in increments of no more than $1.50 up or down, in accordance with District policy.

3.6.3 Frequency

Typically, fewer, well-communicated rate changes carry more weight than frequent modifications. Customers can suffer from communication fatigue if rate changes occur more than four to six times per year. Per the pilot business rules, price changes were implemented in the pilot area on a quarterly basis (every three months).

3.6.4 Thresholds

DDOT established low-and high-end pricing thresholds in the pilot business rules. The low-end threshold was 50 percent of the prevailing District rate ($2.30/hr.) rounded down to the nearest 50 cent increment ($1.00/hr.). The high-end threshold, established by District Council, was $8.00/hr.

3.7 TIME LIMIT ADJUSTMENTS

DDOT also explored time limit increases on block faces where parking spaces were consistently underused, and rate decreases did not encourage drivers to use the spaces. Per the pilot business rules, time limit increases were explored on block phases when on-street prices had been reduced to the prevailing price floor ($1.00). After the third price change was implemented, DDOT identified block faces in the eastern third of the pilot area that exhibited the potential for time limit changes. Following an assessment of block face proximity to local businesses and rush hour restricted corridors, DDOT implemented time limit changes on the eligible blocks in the eastern third of the pilot area. The parking window was increased from two to four hours on weekday evenings after 4 pm and all day on Saturdays.

3.8 LOADING ZONES

DDOT studied loading zone activity to understand how demand-based pricing could also serve commercial vehicles. When parking demand outweighs supply, drivers may resort to parking illegally, including encroaching on loading zones. Thriving businesses in downtown districts must receive deliveries and delivery truck parking and idling can block travel lanes if loading zones are already occupied and off-street loading bays are not available (Figure 3-18). Recognizing that most commercial vehicles do not want to park illegally but will do so when no reasonable alternative is available, DDOT sought to improve the availability of loading zone spaces by analyzing who was using the zones and developing pricing and enforcement strategies from that baseline.

Figure 3-18. Delivery vehicle activity in the pilot area

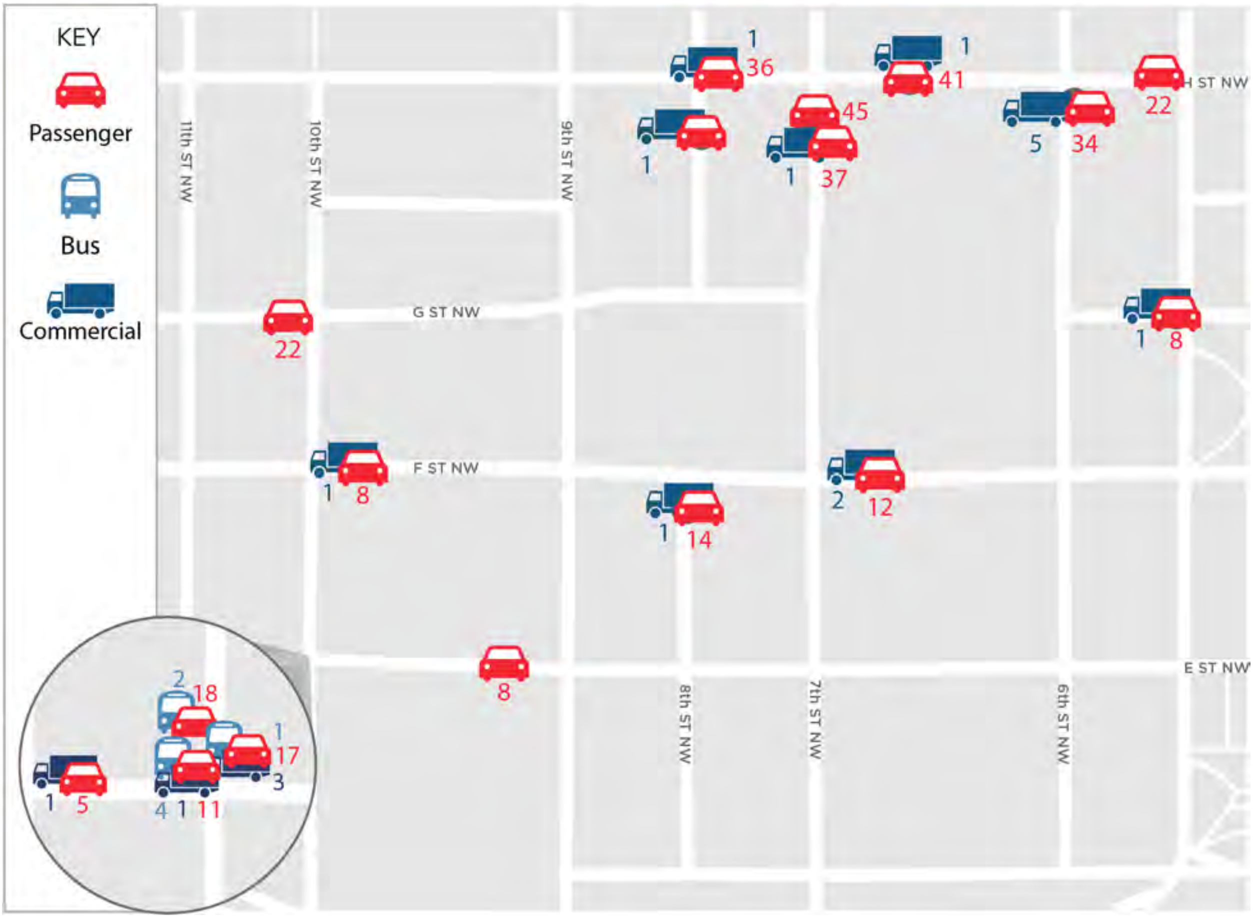
DDOT conducted surveys of loading zone activity in 2016 before the first demand-based price change and after the fifth price change was implemented in 2017. Time lapse cameras were used to gather one week of occupancy data at each loading zone in the pilot area. DDOT collected information about the types of vehicles that used each loading zone (passenger, commercial, or bus), and the duration of all vehicle parking sessions. DDOT also collected vehicle type and session duration information for double parking events.

Loading zones were priced at the prevailing rate of $2.30 per hour when the 2016 video survey was conducted and were in operation until 7 PM. DDOT compared the vehicle type and duration of all parking events in each loading zone to determine whether certain loading zones were experiencing high volumes of unauthorized use. As shown in Figure 3-19, many of the loading zones in the pilot area experienced unauthorized passenger vehicle activity throughout the weekday. Eight of the 16 loading zones observed in the before conditions assessment were occupied by passenger vehicles more than 50% of the time they were in operation. Thirteen of the 16 loading zones experienced a greater number of unique passenger vehicle parking sessions than all other vehicle types.

Figure 3-19. Loading zone activity by zone and vehicle type (2016)

Upon further investigation, the pattern of passenger vehicle encroachment into loading zones continued into the evening, after the spaces were no longer reserved for commercial vehicles. Most vehicles observed using loading zones after 7 PM were passenger vehicles (Figure 3-20). Thirteen of the 16 loading zones experienced nearby double parking throughout the week with double parking sessions ranging in length from five minutes to eight hours.

Figure 3-20. Vehicles parked after 7 PM by vehicle type (2016)



DDOT determined that proactive measures were necessary to discourage the improper use of loading zones in the pilot area. DDOT extended loading zone hours of operation until 10 PM and raised the hourly parking rate at all loading zones to match the highest prevailing on-street parking rate on their associated block faces. If the highest prevailing on-street rate on a given block face was $4.50 during midday, then the loading zone on that block would be priced at $4.50 per hour for all three weekday and Saturday time periods. This higher price was intended to serve as a disincentive to passenger vehicles and other unauthorized users, and the extended hours of operation were intended to improve accessibility for delivery vehicles attempting to access the pilot area during off-peak hours.

3.9 EVALUATION METHODS

This section describes the methodology used to evaluate the effects of the pilot. The evaluation methods are divided into two areas of evaluation:

1. **The system user experience**, which is further divided into three levels:
    - **Level 1: Curbside effects.** DDOT has direct control over these areas, and metrics include the pilot's influence on customer ability to find parking, customer ability to pay for parking, and instances of illegal parking.
    - **Level 2: Pilot area network effects.** The pilot would be expected to impact the surrounding transportation system, and metrics include the availability of parking information, placard use and abuse, and safety.
    - **Level 3: Broader transportation and land-use activity.** This level addresses the wider transportation ecosystem that includes the parkDC pilot. Metrics include broader transportation and land use activity include impacts on multimodal mobility and economic vitality.

2. **The agency perspective** provides the metrics for outcomes desired by DDOT, the managing agency of the parkDC Penn Quarter/Chinatown pilot.

3.9.1 The system user experience

> The system user experience discusses the impacts felt by people parking in the area (level 1), those traveling in or through the area (level 2), and area's businesses and wider transportation ecosystem (level 3).

3.9.1.1 LEVEL 1: CURBSIDE EFFECTS

DDOT has direct control over these areas, and outcomes include the pilot's influence on customer ability to find parking, customer ability to pay for parking, and instances of illegal parking.

3.9.1.1.1 Cruising for Parking Detection

To support the pilot evaluation, DDOT also deployed a network of automated vehicle identification (AVI) sensors to collect data related to vehicles cruising (or circling) for parking. By comparing changes in parking occupancy throughout the pilot to changes in the number of vehicles cruising for parking and how long those vehicles circled for parking, DDOT had another data-driven measure with which to measure the success of the pilot. The analysis methods described here were used for metrics under both curbside effects (level 1) and pilot area network effects (level 2).

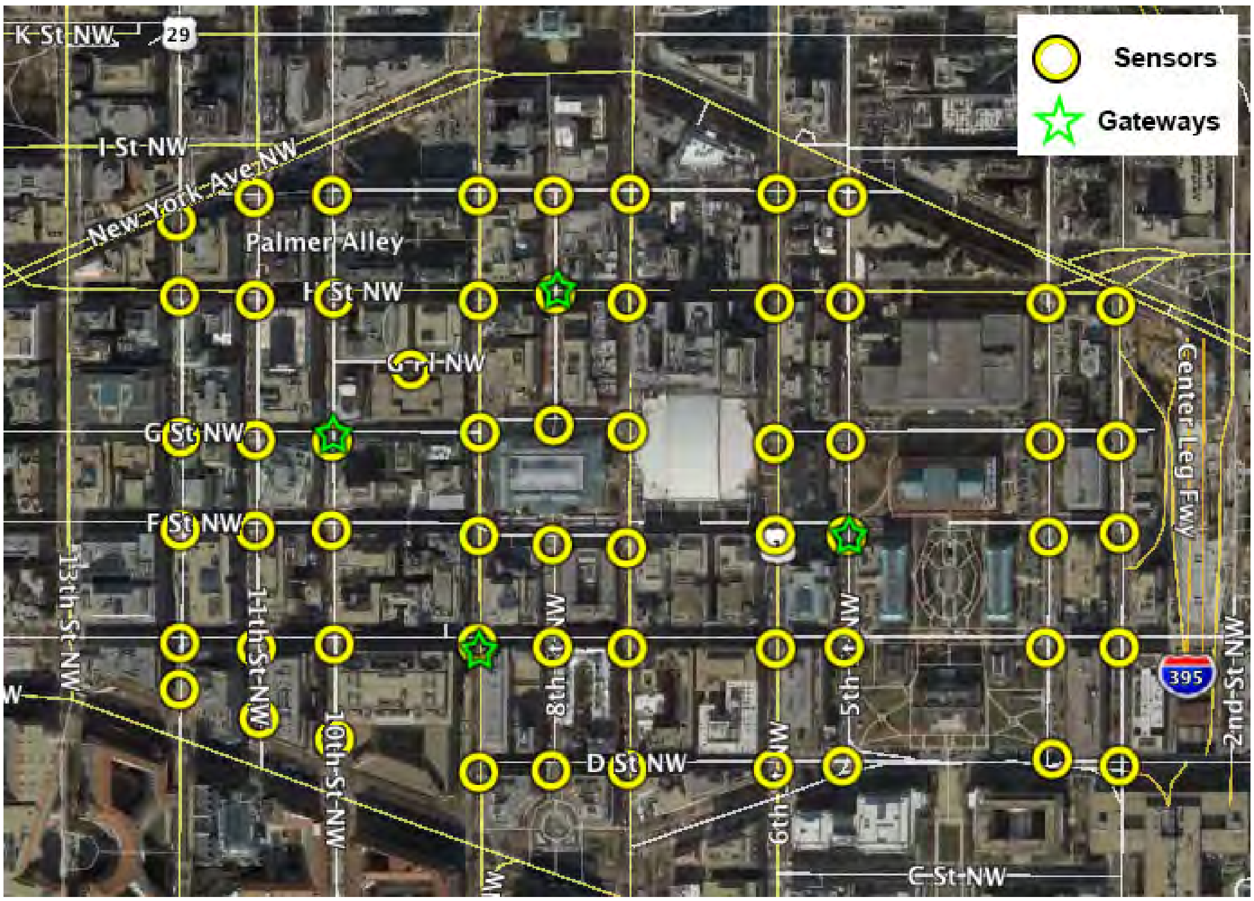
Automatic Vehicle Identification Sensors

Traditionally, travel times have been studied indirectly from field-based observations of counts and occupancy transformed into spot speeds or observed snippets via license plate surveys and other techniques. The advent of automatic vehicle identification (AVI) and automatic vehicle location (AVL) technologies has made it possible to observe travel times directly for individual vehicles. AVI data collection sources, which include Bluetooth readers, detect a passing vehicle at one sensor, then re-identify the vehicle at a second sensor, allowing the vehicle's trip time between two points to be directly computed. AVL data (such as GPS or cellular data) provides a vehicle trace updated within some period. AVI sensors are now widely used by public agencies to measure travel in transportation networks, particularly travel times.

Although AVL technology may provide higher fidelity data than AVI technology, AVI data have several advantages over AVL data. AVL data are not generally available, often requiring commercial purchase or access to restricted datasets. GPS traces produced from navigation devices and apps may include only part of a route (usually while navigation assistance was needed), with biased samples that can exclude regular commuters and the portion of a route that would include cruising. AVI data give cities the ability to own the raw travel data for areas of interest. AVI data is generally unbiased, capturing a cross-section of trip types. In tests leading to this work, Bluetooth penetration rates of 10-20% of vehicles were seen.

In an ideal case, one could collect AVI travel time data continually on every link in the network to improve the accuracy of travel time prediction. However, the cost of installing a single commercial Bluetooth reader is about $10,000. For this reason, current Bluetooth AVI deployments focus almost exclusively on freeway or arterial settings with sparse sensor deployment, rather than dense, urban deployment. However, with the commodification of hardware necessary to construct such readers, readers may be built at much lower cost, opening new possibilities for deployments – including observing circling for parking.

Figure 3-21. AVI sensor network deployment



Sensor Network Deployment

To best measure cruising related to the Penn Quarter/Chinatown Pricing Pilot DDOT chose to deploy a dense network of Bluetooth AVI sensors. DDOT determined that capturing routes that might exit and re-enter the pilot area would improve the quality of measurement. The sensor network extended one block north, west, and south of the pilot area. Interstate 395 forms a natural barrier at the eastern edge of the pilot area, so it was not necessary to extend the network to the east.

DDOT deployed a network of 59 sensors, shown in Figure 3-21, from 3rd to 12th Streets NW and D to I Streets NW. Since DDOT wanted to measure cruising over multiple years, sensors needed to be permanently mounted and connected to an available power supply. A new sensor prototype and new software were developed to ensure the success of the remote data collection effort.

In almost all cases, sensors were located at an intersection, but in a few cases, it was necessary to install them closer to the middle of a block. Rather than install a sensor at each end of G Place NW, it was only necessary to install a single sensor in the middle of the block, since the street is only one block long. The three sensors located near intersections on Pennsylvania Avenue NW (10th, 11th, and 12th) were installed away from the intersection toward E Street, since most of the poles at intersections on Pennsylvania Avenue are designed to be removable for events on Pennsylvania Avenue, like presidential inaugurations. Though installation at the intersection is generally more desirable, these location adjustments were expected to have little to no effect on data quality.

The sensor network was deployed during the summer of 2016, with complete operation in place by September 2016. Four gateways for remote data collection were also installed. The automated cruising for parking data used the same time bands as the DDOT time-of-day pricing bands, with further segmentation for rush hours (Table 3-4).

Table 3-4. Cruising for parking analysis time bands

Morning Peak 1	Morning Peak 2	Mid-day	Afternoon Peak	Evening
7:00–9:30 AM	9:30–11:00 AM	11:00 AM–4:00 PM	4:00–6:30 PM	6:30–10:00 PM

3.9.1.1.2 Time to Find Parking Manual Surveys

DDOT conducted manual parking search time surveys to supplement cruising data collected by AVI sensors. To collect the data, DDOT used a technique also used by SFpark[1] which assumed that drivers searching for parking travel at approximately the same speed as bicyclists. The manual surveys were conducted via bicycle in the pilot area and in a control area on both weekdays and Saturdays. Surveyors bicycled through the pilot and control areas along pre-defined routes in search of parking spaces. The number of bicycle search runs, elapsed time between the start of each search and location of a suitable parking space, and the number of laps of the survey route run during each search were recorded.

These manual surveys were conducted twice: once before the first price change was implemented and once following implementation of the fourth price change. Figure 3-22 outlines the time to find parking manual survey process.

[1] http://sfpark.org/resources/survey-deployment/

Figure 3-22. Parking Search Time Survey Process

The time to find parking survey process used slightly different time bands than the DDOT time-of-day pricing bands (Table 3-5).

Table 3-5. Time to find parking manual survey time bands

Weekday AM 8:30 – 10:30 AM	**Weekday Midday** 12:00 – 2:00 PM	**Weekday PM** 5:00 – 7:00 PM
Saturday Midday **12:00 – 2:00 PM**	**Saturday PM** **4:00 – 8:00 PM**	
Sunday Afternoon **1:00 – 5:00 PM**		

3.9.1.1.3 Parking Enforcement and Compliance

Parking enforcement is necessary for ensuring greater parking availability and turnover. It is a key consideration in implementing parking management strategies. At a broad level, other jurisdictions found that when parking management strategies are properly implemented, enforcement revenue typically decreases, despite increases in the amount of enforcement conducted. When parking spaces are easier to find and more available, drivers are less likely to park illegally. DDOT sought to improve compliance both by increasing parking availability and by improving traveler information, notably with a highly visible parking decal on each multi-space meter that detailed prices and parking restrictions by time of day (further detailed in Chapter 4). To evaluate compliance and enforcement, DDOT looked at both placard use and citation issuance.

Double Parking

Since double parking contributes to downtown congestion and can result from an imbalance in parking supply and demand, DDOT sought understand how the parkDC pilot may have affected double parking. Data was collected on two weekdays along a pilot route located within the pilot area and a control route located in close vicinity to the pilot area (Figure 3-23). Both routes included over 70 parking spaces, a large enough number to produce a statistically significant result in a before and after comparison. In both the before and after conditions, data was collected in six time bands between 8:00 AM and 7:30 PM.

Figure 3-23 Double Parking Survey Map

The analysis of loading zones (discussed in section 3.8, above) using time-lapse cameras also allowed DDOT to assess changes in double parking associated with loading zones and motorcoach zones.

Citations

Within the District, parking enforcement is under the jurisdiction of DPW. During the conversion to pay-by-space, DDOT worked with DPW to develop enforcement procedures and update software to allow for integration software used by enforcement officers' handheld enforcement devices and DDOT's system. This coordination also included training sessions with all enforcement officers who work in the pilot area. However, enforcement in the pilot area was inconsistent following these changes due to a mix of improper enforcement or enforcement officers avoiding the pilot area. Consequently, DDOT is unable to determine whether compliance was improved in the pilot area. For informational purposes, citation data was still analyzed (Chapter 5) but with the caveat that conclusions cannot be drawn from the data. For each price change, the data includes two full months of citation data within the pilot area, for the period shown in Table 3-6. In time periods with more than two months in between price changes, DDOT chose months that align with months from other price changes to control for seasonality.

Table 3-6. Citation data analysis time periods

Period	Start Date	First Month	Second Month
Before Changes	N/A	June 2016	July 2016
Price Change 1	10/17/2016	December 2016	January 2017
Price Change 2	2/20/2017	March 2017	April 2017
Price Change 3	5/30/2017	June 2017	July 2017
Price Change 4	8/28/2017	September 2017	October 2017
Price Change 5	11/6/2017	December 2017	January 2018

3.9.1.2 LEVEL 2: PILOT AREA NETWORK EFFECTS

This part of the evaluation addresses impacts to the surrounding transportation system, including the availability of parking information, placard use and abuse, and safety.

3.9.1.2.1 Placard Use

Placard usage can contribute to the poor correlation between payment data and real-time occupancy data in DDOT's data fusion process. DDOT measured placard use in the pilot area before and after pilot implementation to determine whether parking availability for paying customers increased, decreased, or stayed the same during the pilot. DDOT conducted a survey of placard use before the first price change was implemented in October 2015 and after the fifth price change was implemented in November 2017.

DDOT conducted surveys of placard use in concert with surveys of double parking in 2015 and 2017 (see section 3.9.1.1.3 for more on the double-parking survey).

3.9.1.3 LEVEL 3: BROADER TRANSPORTATION AND LAND-USE ACTIVITY

This is the wider transportation ecosystem that included the parkDC pilot. Metrics include broader transportation and land use activity and impacts on multimodal mobility and economic vitality.

3.9.1.3.1 Districtwide Trends

Changes to the District's population, employment, travel demand, economic activity, and multimodal transportation network can influence parking demand in the District, including the areas studied in the parkDC pilot. DDOT reviewed U.S. Census data from 2015 to 2017 to identify trends potentially impacting parking demand.

3.9.1.3.2 Congestion

Major roads in the pilot area traditionally experience high levels of congestion and low travel time reliability. The parkDC pilot sought to alleviate this congestion through improved access to parking. Improved access to parking was expected to reduce circling for parking and double parking, both of which contribute to congestion. DDOT attempted to measure the effect of demand-based pricing on traffic congestion and double parking.

To evaluate the effects the pilot had on traffic congestion, changes in the Travel Time Index (TTI) and Planning Time Index (PTI) were calculated for 2015, 2016, and 2017. TTI is the ratio of average or median travel time to the time required to make the same trip at free-flow speeds. For example, with a TTI of 1.2, a trip that takes 20 minutes at free-flow speeds would have an average or median travel time of 24 minutes. PTI is the ratio of travel time during the worst conditions (95th percentile travel time) to the time required to make the same trip at uncongested speeds. For example, with a PTI of 1.2, a trip that typically takes 30 minutes in light traffic would require drivers to plan for 36 minutes to arrive on time.

3.9.1.3.3 Economic Analysis

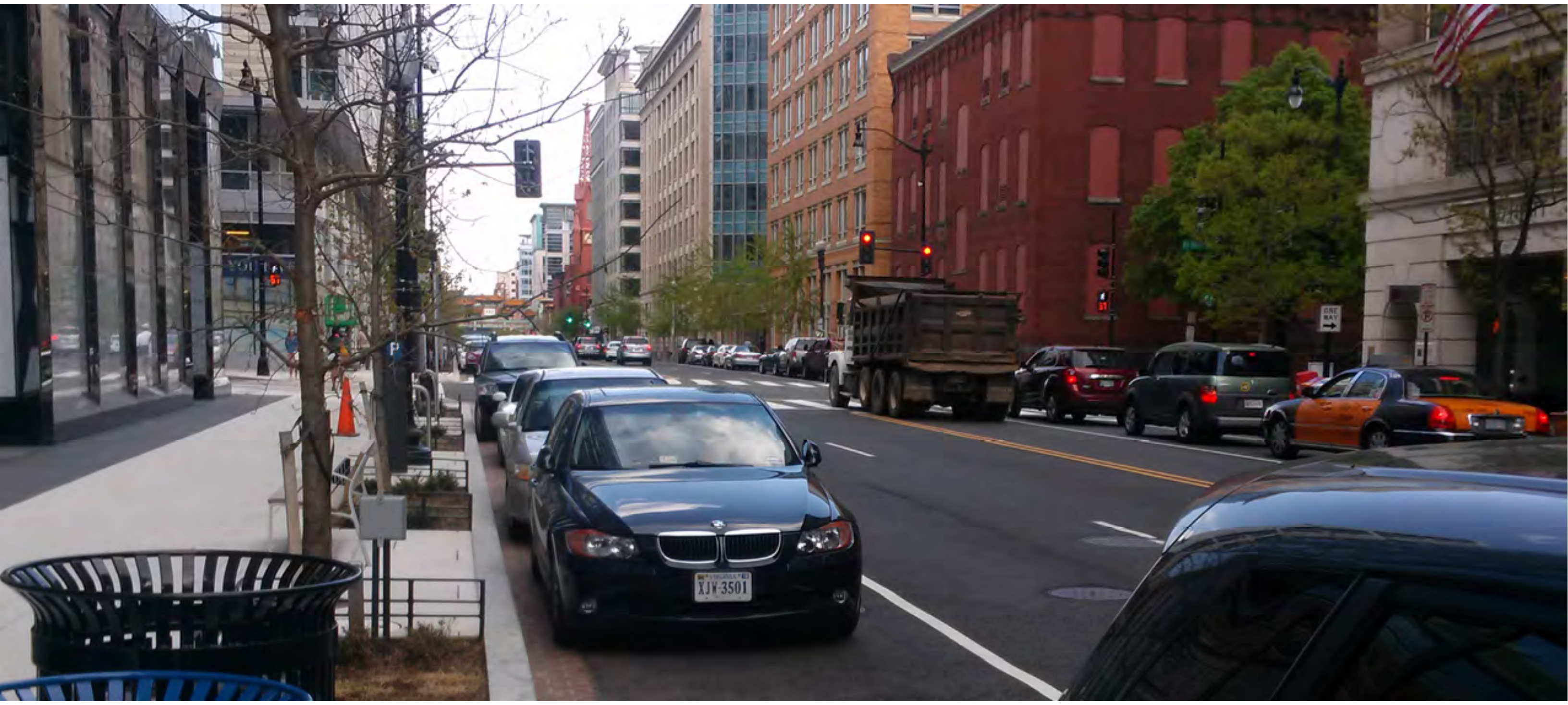
Parking access directly relates to people's access to school, work, entertainment, food and shopping. DDOT reviewed business point data provided by a private entity for 2015, 2016 and 2017. This data was used to identify whether the pilot impacted economic activity in the Penn Quarter/Chinatown neighborhoods.

3.9.1.3.4 Multimodal Performance

In an urban area like the Penn Quarter and Chinatown neighborhoods, the relationships between various modes of travel make it likely that when operations for one mode changes, the other modes are affected. DDOT looked at performance for bus transit, rail transit, and bikeshare.

For transit, DDOT looked at data from the Washington Area Metropolitan Transit Authority (WMATA) Metrobus and Metrorail services. Multiple bus lines come through the pilot area and there are three Metrorail stops within the pilot area providing access to all rail lines. DDOT assessed annual trends in bus speeds and transit ridership to understand how the parkDC pilot may have impacted transit performance when compared to the District as a whole.

Founded in 2010, Capital Bikeshare is metropolitan Washington's bikeshare system. With over 4,000 bikes and 500 stations serving the District, Maryland, and Virginia, the service expands bicycling options for residents, commuters, and visitors. Within the pilot area, several Capital Bikeshare stations are available in the Penn Quarter/Chinatown area. After the pilot was implemented, DC has expanded access to alternative modes through the introduction of dockless bikeshare and scooters. These dockless, inexpensive modes of transportation can be found Districtwide. DDOT reviewed ridership on the Capital Bikeshare system for stations in the pilot area compared to the system as a whole.



3.9.2 The agency perspective

> This section provides the metrics for outcomes desired by DDOT, the managing agency of the parkDC Penn Quarter/Chinatown pilot.

3.9.2.1 CUSTOMER EXPERIENCE

DDOT conducted a before and after survey to begin to understand how the parkDC pilot had affected stakeholder parking experiences. A QR code and web address were provided on the back of every receipt provided to customers after paying to park in the pilot area directing them to the survey. The survey asked responders about how often they drove or parked in the pilot area, how long it took to find a parking space, whether they thought about traveling by another mode, the clarity of the parking regulation information, and their experience finding an open parking space. More information on the customer experience is provided in Chapter 4.

3.9.2.1.1 Parking Information Accuracy

DDOT conducted five accuracy tests before and after both mobile applications were launched in December 2016. The tests aimed to understand how accurately the apps were predicting occupancy compared to what was observed on site. As part of each test, surveyors walked the pilot area and compared outputs from the mobile applications to observed real-time occupancy to see whether the mobile applications were reporting accurate information. After each test, results were scrutinized to identify accuracy issues and determine which component (app or algorithm) was causing errors.

3.9.2.2 FINANCIAL AND COST EFFECTIVENESS ANALYSES

DDOT assessed the affect that the parkDC pilot had on DDOT's parking-related revenues from meters and mobile payments. While improving the customer experience is the primary goal of parkDC: Penn Quarter/Chinatown, the project team has also considered the effects of demand-based pricing on revenue. A benefit-cost analysis assesses whether DDOT should expand the parkDC model to other neighborhoods in the District.

CHAPTER 4

Stakeholder Outreach & Coordination

Reducing the time to find an available parking place

4 Stakeholder Outreach and Coordination

Stakeholder buy-in was one of the keys to success for the parkDC pilot. This section summarizes how DDOT generated support through a robust and comprehensive outreach and coordination effort.

4.1 NEED FOR EFFECTIVE COMMUNICATION

Introducing and implementing a concept that uses price to manage demand comes with some inherent risks. Unless policymakers and the public are educated about the goals, approach and benefits, there is the risk of such efforts being construed as "price gouging." To mitigate the risks, DDOT adopted a conservative, incremental approach to its price change strategies. In addition, the project team recognized the importance of taking a thoughtful, comprehensive approach to stakeholder coordination and customer outreach. This approach was instrumental in helping the project avoid negative customer response or press coverage, both of which could have derailed it before the pilot could be completed and undermined any potential for future expansion. This chapter presents the overall communication strategy and describes the stakeholder identification, outreach, and customer experience.

4.2 COMMUNICATION STRATEGY

The communication strategy was guided by the Communication Plan (found in the Data Book), which established goals and objectives, defined stakeholders, identified key messages, laid out an outreach strategy, identified appropriate outreach materials and channels of communication, specified a timeline and outlined how the results of the pilot would be presented to stakeholders.

DDOT established the following goals for the communication plan, noting that they would shift throughout the course of the pilot:

- Inform stakeholders of the design, execution, and refinement of the pilot
- Generate public support for the pilot
- Help stakeholders and public better understand how the pilot works
- Keep stakeholders aware of the pilot's status, and inform stakeholders of the results of the pilot and considerations for ongoing deployment

4.3 STAKEHOLDER IDENTIFICATION

DDOT identified stakeholders for the project and detailed how the project team would address their respective needs throughout the pilot. The communication plan included a detailed profile of each stakeholder that outlined their primary needs, project impacts, benefits, and risks. The stakeholders identified by the project team and engaged throughout the pilot are summarized in Table 4-1.

Table 4-1 Pilot Stakeholders

Stakeholder	Group	Role
District Department of Transportation	Planning & Sustainability Division	▪ Research, freight
	Parking & Ground Transportation Division	▪ Curbside management planning and operations ▪ Coordination with DDOT curbside management initiatives
	Information Technology & Innovation Division	▪ Technology deployment coordination
	Community Engagement Division	▪ Customer outreach
	Policy and Legislative Affairs Division	▪ Parking policy
	Traffic Operations and Safety Division	▪ Signs and markings ▪ Intelligent transportation systems
	Customer Service Clearinghouse Division	▪ Customer outreach
Other District Agencies	Department of Public Works	▪ Parking enforcement
	Department of Motor Vehicles	▪ Adjudication
	Office of Unified Communication	▪ Customer service calls
	Metropolitan Police Department	▪ Enforcement
	Office of the Chief Technology Officer	▪ Intelligent voice recognition system for call intake ▪ Data collection and technology testing ▪ Mobile application deployment
Businesses and Commercial Entities	DowntownDC Business Improvement District	▪ Information sharing ▪ Customer and community outreach
	Penn Quarter Neighborhood Association	
	Motorcoach /Freight trade groups	
	Washington Parking Association	
	Apartment and Office Building Association add Verizon Center/Capital One Arena	
Media	Print	▪ Information sharing ▪ Customer and community outreach
	Radio	
	TV	
	Blogs	
	Social Media	

Stakeholder	Group	Role
Policy/ Decision-Makers	Executive Office of the Mayor	▪ Information sharing ▪ Executive approvals
	Council of the District of Columbia	▪ Information sharing
	Advisory Neighborhood Commission 2C Leadership	▪ Information sharing ▪ Customer and community outreach
Customers	General Public	▪ Information sharing
	Washington Area Bicycle Association	▪ Information sharing ▪ Community outreach
DC Residents	Advisory Neighborhood Commission 2C Neighborhoods	▪ Information sharing ▪ Customer and community outreach

4.4 OUTREACH AND MESSAGING

DDOT identified and distributed key messages throughout the pilot at significant project milestones to clarify stakeholder issues and answer frequently asked questions. These key milestones included the launch of the pilot, migration to demarcated curbside parking, and prior to each price change, including the launch of the real-time mobile applications in conjunction with the first price change. The pilot team adapted the messaging for the outreach program as their understanding of common stakeholder concerns evolved.

After identifying stakeholders and initial key messages, DDOT developed a detailed outreach plan and associated materials to effectively communicate with all pilot stakeholders. The three primary outreach strategies used in the pilot included email updates, in-person meetings, and outreach through social media and other online platforms. The following outreach materials were developed:

- **Summary Flyer**: Used to convey key messages to a general audience, the flyer included contact information, so stakeholders could request more information or ask questions (Figure 4-1).
- **Press Releases**: Disseminated throughout the duration of the pilot, the press releases provided news announcements, updates on key milestones, and project status updates.
- **Frequently Asked Questions (FAQs) Documents**: Distributed in conjunction with press releases, the FAQs reflected changing pilot goals and key messages.
- **Formal Letters**: Delivered to local Advisory Neighborhood Commissions (ANC—the District's smallest unit of representative local government) and other stakeholders in advance of each rate change.
- **Public Presentation Material**: A standard public presentation was developed to provide pilot information to a general audience at public meetings and other in-person events. The presentation was updated throughout the pilot to reflect the changing project status and key messages.

- **Website**: Developed to provide pilot information to stakeholders. Along with a dedicated web page on DDOT's official website, the pilot website served as the primary source of information for stakeholders. It included links to the latest press release, FAQ documents, and the public presentation.
- **Social media:** Used to convey timely messages and responses to customer concerns.
- **Advertising:** Used to draw attention to upcoming project milestones, including advertisements for the mobile applications on bus shelters in the pilot area.
- **On Street Ambassadors.** Supported the transition to pay-by-space by providing answers to customers in the field as they were paying for parking.

Figure 4-1 parkDC Summary Flyer

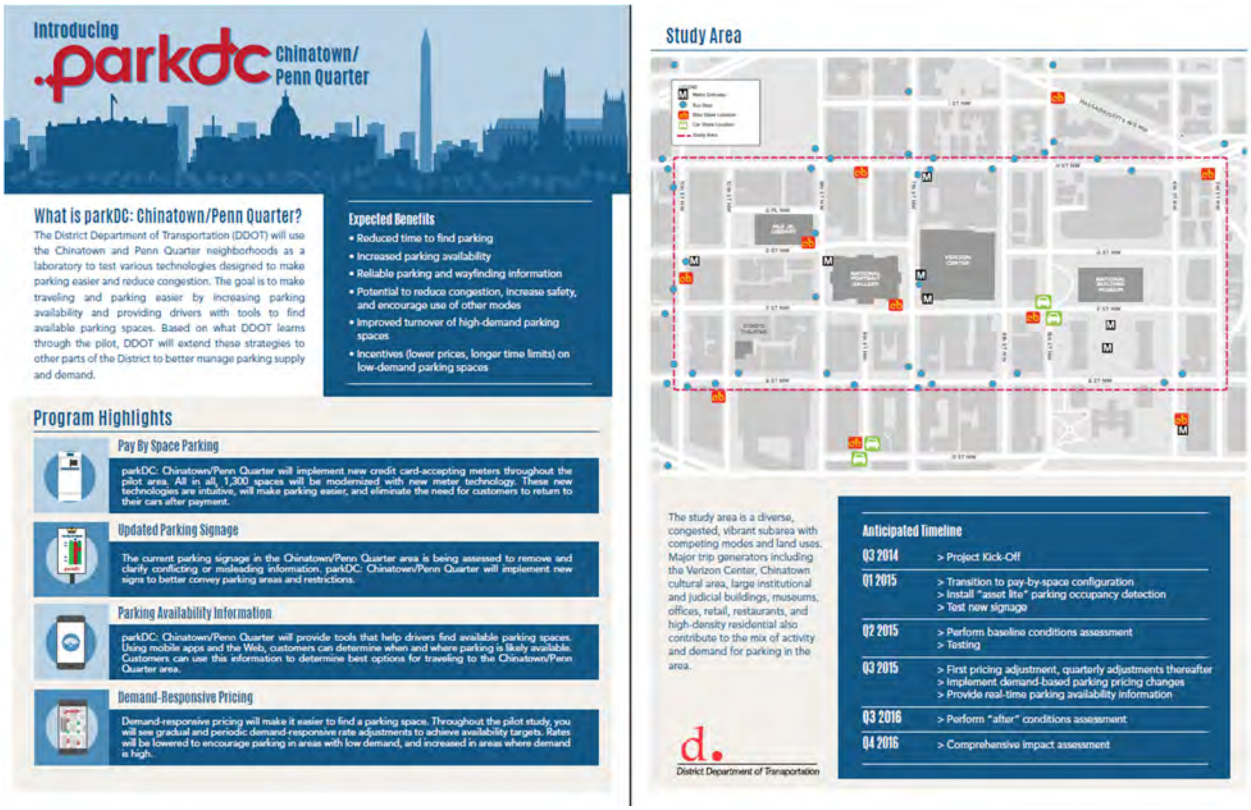
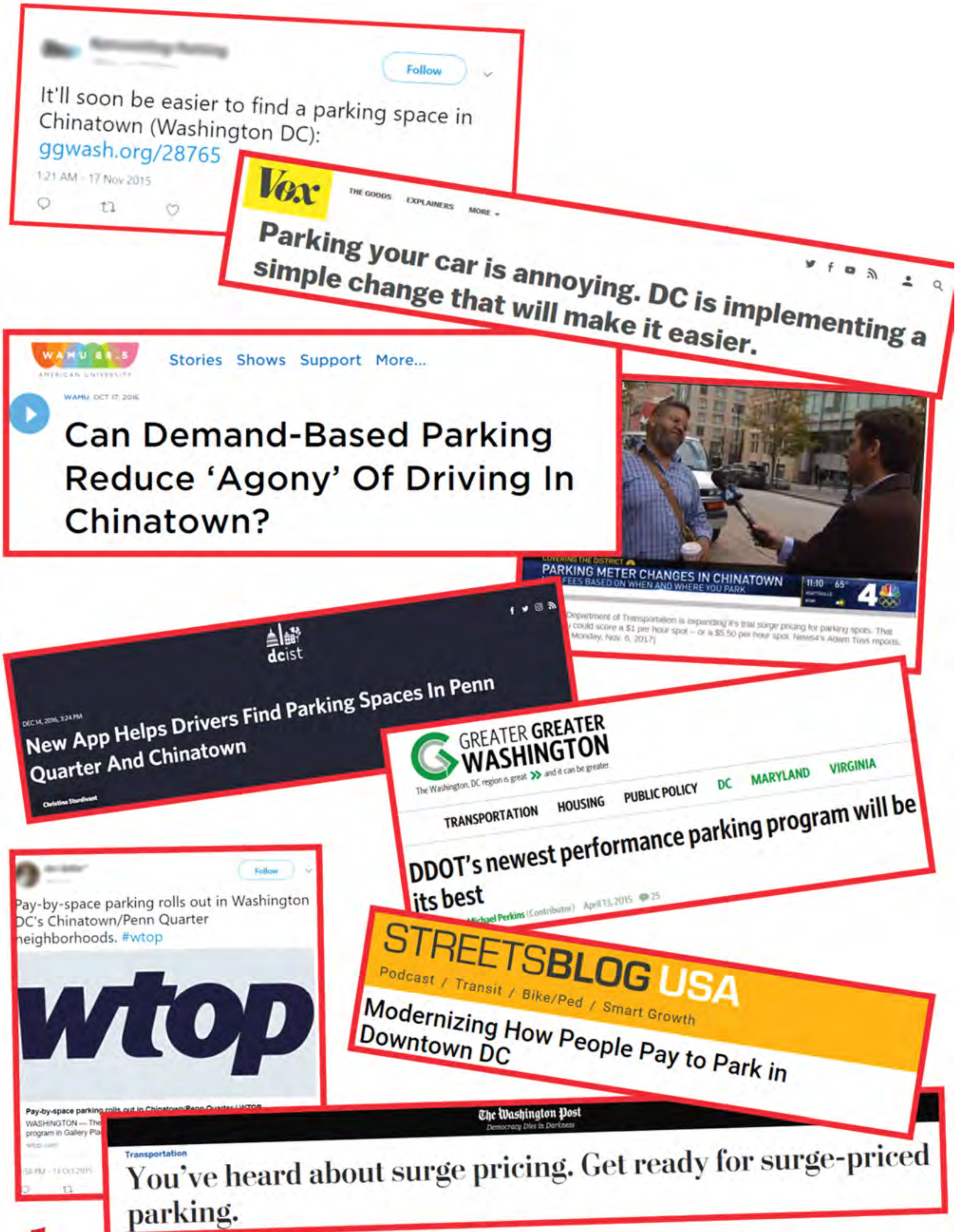


Figure 4-2. Selection of headlines from media outlets about the pilot



Based on the Parking Pricing Business Rules developed at the start of the pilot, DDOT aimed to inform stakeholders about each upcoming price change at least 10 business days prior to the implementation date.

As part of the stakeholder coordination and customer outreach effort, DDOT held media events, spoke at numerous public meetings, held meetings with the Downtown DC Business Improvement District (BID) and the Penn Quarter Neighborhood Association, conducted a press event for local media, and submitted papers and abstracts to multiple annual transportation and parking conferences (Table 4-2).

Table 4-2. Sampling of Outreach Events

Event	Type	Date
Media Events	Project Overview Media Briefing	December 2014
	Pay-By-Space Conversion Media Outreach	October 2015
	First Price Change Media Briefing	October 2016
	Fox 5 DC Interview	December 2016
	Washington Post interview	November 2015, February 2017
Public Meetings	Ward 2 ANCs	February 2015, September 2015, October 2016, February 2017, July 2017, September 2017
	Pay-By-Space Community Outreach	April 2015
Stakeholder Meetings	DowntownDC BID	December 2014, January 2017, February 2017, May 2017
	Penn Quarter Neighborhood Association	September 2015, October 2016
	Council Member Meetings	March 2015
	Federal Highway Administration	March 2015, January 2017, October 2017
	Parking Garage Operators	March 2015, May 2016, September 2016
Conference Presentations	**Institute of Transportation Engineers**	
	▪ Mid-Colonial District Meetings	April 2015, April 2016, April 2017
	▪ Washington D.C. Section Meeting	April 2016
	International Parking Institute	
	▪ IPI Conference & Expo	June 2015
	▪ Webinar	September 2015
	Intelligent Transportation Systems	
	▪ ITS America	June 2016
	▪ World Congress	October 2017
	Transportation Research Board	
	▪ parkDC: Penn Quarter and Chinatown--Sustainable Approach to Performance Pricing for Parking in Washington, D.C.	January 2016
	▪ Asset-Lite Parking: Using Big Data Analytics to Develop Sustainable Smart Parking Solutions in Washington, D.C.	January 2016
	▪ "To Demarcate or Not to Demarcate" On-Street Parking Spaces: Analytical Approach	January 2016
	▪ Hunt for Perfect Parking Occupancy Detection: Evaluation of Technologies and Their Ability to Address Urban Challenges	January 2017

Event	Type	Date
	▪ Sensors and the City: Urban Challenges for Parking Occupancy Detection and Pricing	January 2018
	▪ If You Price It, Will They Change? Assessing the Effects of Demand-Based Parking Pricing on Customer Behavior in Washington, D.C.	January 2018
	▪ Measuring Cruising for Parking in Washington, D.C., Using Dense, Ubiquitous AVI Sensor Networks	January 2018
	National Parking Association	October 2018
	Federal Highway Administration	
	▪ FHWA Workshop on State of the Practice: Contemporary Tools and Approaches to Parking Pricing and Management	March 2016
	▪ Congestion Pricing Workshop	May 2018
	Global Cities Team Challenge	May 2015, August 2017
	Mid-Atlantic Parking Association	November 2017
	Georgetown Smart Cities Assembly	April 2016, April 2017

This report and associated documents (Executive Summary and Data Book) comprise the final element of the pilot's communication plan, which seeks to inform all stakeholders about the pilot findings and recommendations for expanding demand-based parking pricing in the District.

4.5 CUSTOMER EXPERIENCE

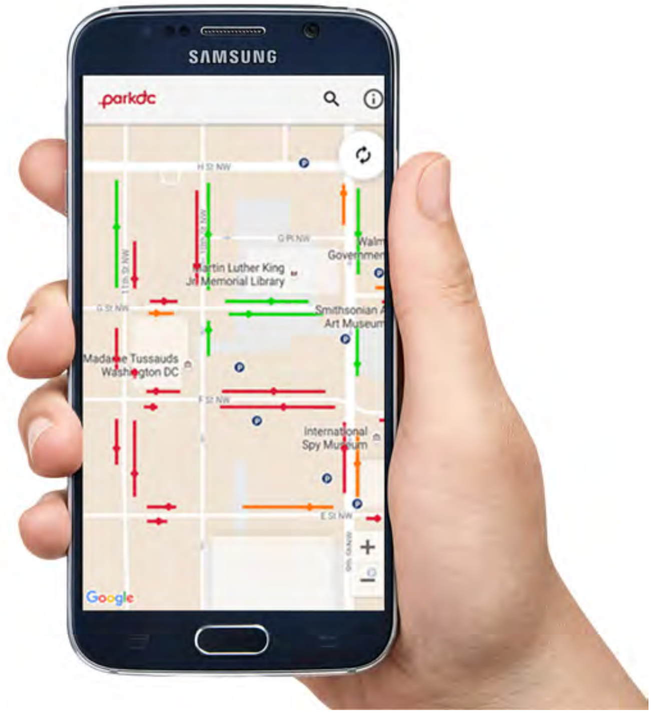
When describing the "agony" associated with finding parking, customers most often referenced finding and paying for parking. The pilot team viewed informing the search for parking as an opportunity to improve the customer experience while also mitigating issues leading to downtown congestion, such as circling for parking and double parking. Along with providing stakeholders with advance notice of impending pricing changes, DDOT employed a range of strategies to make it easier for people to find and pay for parking in the pilot area, including customized meter decals, a new parking sign design pilot, and mobile applications with real-time traveler information.

4.5.1 Real-Time Traveler Information

The parkDC team deployed an Application Programming Interface (API) which is a software go-between that allows two applications to speak to each other, available upon request to software developers or researchers. The API provides real-time information on parking pricing and occupancy data for the pilot area. DDOT worked with application (app) developers to release two high-quality mobile apps: parkDC and VoicePark.

Recognizing that real-time information was a central component of the pilot's communication strategy, DDOT wanted to make multiple real-time portals available to customers where they could access this information. Since the real-time parking availability app development industry was in a state of flux, DDOT chose to develop its own mobile app while continuing to make the API available to independent developers. The parkDC app developed by DDOT provides parking availability and rate information for on-street parking in the zone, and importantly ensures that real-time information will remain available to customers. On-street availability is shown using green, orange and red lines, which indicate low, medium or high numbers of spaces available (Figure 4-3). Current hourly prices are provided for each block. The parkDC app also provides location, daily rates and hours of operation for parking garages. parkDC has been downloaded at a rate of approximately 300 users per month since it was released in December 2016, with approximately 2,600 total downloads.

Figure 4-3 Screen captures of the parkDC mobile application



VoicePark, developed by an independent app developer, delivers turn-by-turn guidance to available on- or off-street parking in the zone area. The app shows the estimated number of available on-street spaces along with hourly rates (Figure 4-4). VoicePark also provides location, daily rates and hours of operation for area parking garages. VoicePark has been downloaded at a rate of approximately 310 users per month, and users have initiated an average of 8.3 sessions since the app was released in December 2016. It takes less than a minute for VoicePark's server to notify the VoicePark team when their system is down in the DC pilot area, and less than one hour after that to restore service.

Figure 4-4 Screen capture of the VoicePark mobile application

The VoicePark team provided DDOT with quality assurance/quality control assistance throughout the app deployment process, sharing real-time data about outputs from DDOT's API for the team to compare with outputs from the pilot's internal system. VoicePark's input helped the pilot team fine tune the API.

Both apps allow stakeholders to see how likely they are to find parking on a given block face and how much it would cost to park there. Stakeholders can use this information to decide whether they will drive to their destination or choose to walk, bike, or use transit instead. If they decide to drive, they will know where to look for parking. The apps aimed to take the guesswork, trial and error, and unnecessary circling out of users' travel. Advertisements for the parkDC app were placed in transit shelters in the pilot area, and all parking meter decals included information about it and a mention of the VoicePark app. Both apps were also referenced in all press releases and in most of the stories published by media outlets.

The parkDC team conducted a series of independent quality assurance/quality control tests on both apps and generally found that the accuracy of both apps improved over the year they were in operation. The results of this QA/QC process are described in greater detail in Chapter 5.

Full results of the mobile application quality assurance/quality control assessments can be found in the parkDC Data Book.

4.5.2 Paying for Parking

The parkDC pilot sought to make it easier for customers to pay for parking by transitioning from a pay-and-display environment to a demarcated, pay-by-space configuration (Figure 4-5). In addition to occupancy detection benefits offered by the pay-by-space configuration, demarcated environments are generally more convenient. The pay-by-space configuration removes the need for users to return to their vehicle to display a receipt after paying. It is also easier for drivers of convertibles and motorcycles to comply in a pay-by-space area. It is difficult to display a receipt on a motorcycle, and in a convertible, a receipt can easily be stolen or lost. The pay-by-space environment also provides increased operational efficiencies, since there is no risk of paper jams at pay-by-space kiosks.

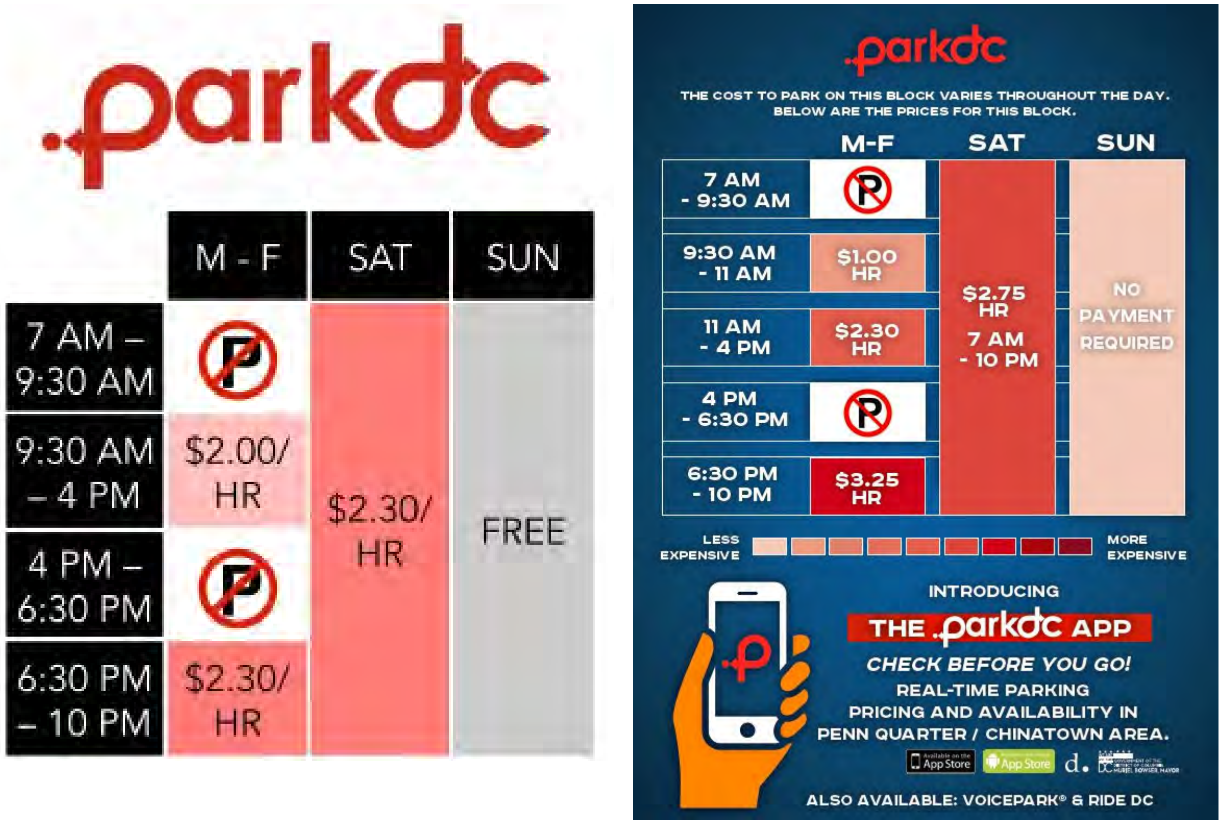
Figure 4-5. Pay-By-Space Parking Configuration

Figure 4-6. Meter decal and sign survey deployed in the field

4.5.3 Parking Meter Decals

The pilot team needed an eye-catching approach to inform motorists about new curbside rates in the pilot area. Parking meters in the pilot area were programmed to reflect the latest prices for each block, but unless a stakeholder was already preparing to pay for parking at a meter they were unlikely to know the prevailing parking rate. The pilot team employed calendar-style decals originally developed in New York City[1] and implemented in other cities across the country, to provide stakeholders with a snapshot of the prevailing parking rates on each block in the pilot area. The calendar style signs increase the clarity of the parking regulations and the project team hypothesized that they may reduce accidental improper parking during peak hour restrictions and other times when parking is prohibited. The 8.5 x 11 decals were placed on all pay-by-space meters and used bright colors and the parkDC logo to inform stakeholders that they were in a demand-based pricing zone. Further, the pilot team opted for a consistent color gradient across all decals (rather than using a scale specific to each decal's price range) to make it easier for customers to identify blocks that are cheaper or more expensive.

Figure 4-7. Initial Meter Decal (left) and Current Meter Decal (right)



[1] Elizabeth Stinson. *A redesigned parking sign so simple that you'll never get towed.* Wired. July 2014. https://www.wired.com/2014/07/a-redesigned-parking-sign-so-simple-youll-never-get-towed-again/

The pilot team deployed the parking meter decals at the start of each price change and received positive anecdotal feedback from stakeholders who used the decals to help identify cheaper blocks (Figure 4-7).

4.5.4 Sign Inventory and Plan

Although much of the curb use and parking pricing information associated with the pilot was communicated to stakeholders via the website, mobile applications, and meters and associated decals, regulatory signage was and continues to be a key component of the parking system. The pilot team conducted a sign inventory and developed a plan to reduce clutter and increase the clarity of parking signs in the pilot area.

The sign inventory included geo-coding all parking signs in the pilot area, preparing geographic information system (GIS) mapping to indicate the allowable use of curbs in the pilot area, creating a curb data inventory that was consistent and compatible with other sign inventory activities at DDOT, and coordinating with DDOT's chief technology officer to ensure compatibility. The pilot team used Esri's ArcGIS Collector tool to document the location and type of each sign in the pilot area. After conducting the conditions assessment, the team provided recommendations as to whether or not signs should be removed, maintained or replaced in a detailed sign plan. Figure 4-8 shows an excerpt from the sign inventory and sign plan.

Figure 4-8. parkDC Sign Inventory and Sign Plan Recommendations

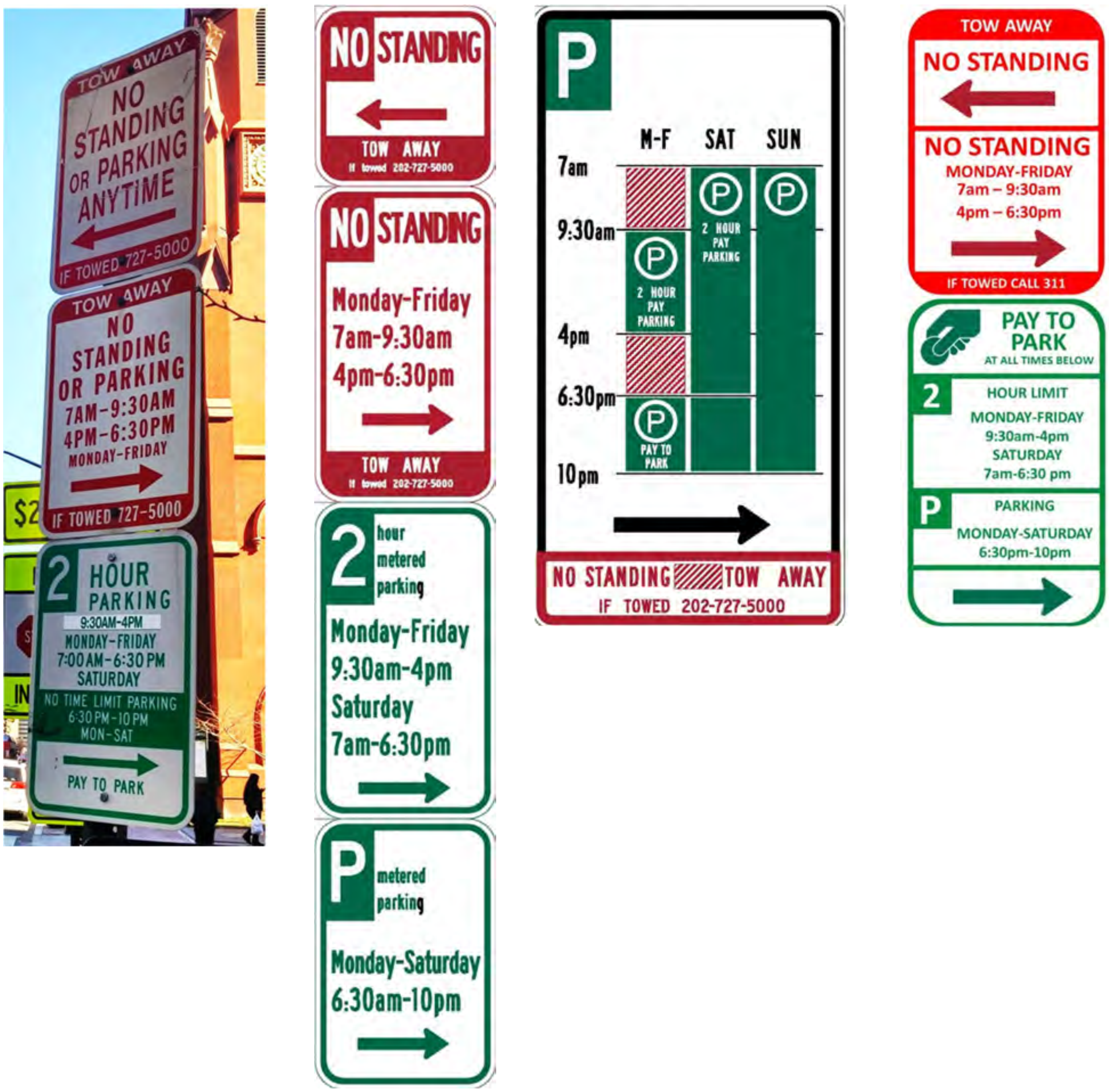
Pole ID	Location Map	Current Sign			Proposed Sign			Category	Comments
		Photo	Sign ID	Sign Type	Photo	Sign ID	Sign Type		
203,753			{384C9098-FE47-4F78-982F-BABF909E7D9D}	R-NS-046: HC	-	-	-	Remove Sign	Remove existing R-NS-046 sign; Remove pole
			{42B08703-4D8F-4E99-A5CF-D1FF0103CBA2}	R7-108: Limited Time Parking	-	-	-	Remove Sign	Remove existing R7-108 sign; Remove pole
203,754			{C9F42941-8350-4C26-B391-5C14ECFB08BB}	R-NS-046: HC			R-DC-PTPCOIN; R-DC-PBC_PLAQUE	Replace Existing	Remove existing sign and install new R-DC-PTPCOIN and R-DC-PBC-PLAQUE signs;

The pilot's sign plan also included preparing a set of sign shop orders to replace parking signs within a subarea bounded by and inclusive of 9th Street NW to the west, H Street NW to the north, 7th Street NW to the east, and E Street NW to the south. The new signs, designed to improve legibility and reduce clutter, were installed in September 2016 (Figure 4-9). A view of the original signs, other proposed sign options, and the recommended design which became the new signs, are seen in Figure 4-10. As shown, the signs were made to be more concise and provide higher-level information at the top.

Figure 4-9. Pilot sign and placard advertising sign survey

The pilot team released an online survey in conjunction with the sign installation to collect stakeholder feedback on parking signage in the pilot area and the District at large. While the results of the survey were not statistically significant, they indicated that stakeholders preferred calendar style signs (such as the parkDC meter decal) and the new pilot signs to the parking signs traditionally used in the District. The survey also indicated that it took survey respondents less time to interpret calendar style signs than all other sign types, and that survey respondents were more confident about their interpretation of the calendar style signs.

Figure 4-10. Prior sign (left) proposed new signs (middle) and recommended sign (right) in the pilot area



CHAPTER 5
Pilot Impacts

Source: Bruce Emmerling, pixabay

What worked? Public and agency perspectives

Source: Wikimedia Commons, AgnosticPreachersKid

5 Pilot Impacts

parkDC's asset-lite approach to demand-based pricing can effectively improve parking availability and utilization, and functions as well as the typical approach for a fraction of the cost.

The asset-lite approach to demand-based pricing distinguishes the parkDC pilot from previous demand-based pricing projects. DDOT also advanced the state of the practice through exploration of multimodal demand-based pricing (i.e., loading zone pricing). Lessons learned from parkDC could enable DDOT to expand demand-based pricing to other zones in the District and serve as a guide for other jurisdictions seeking to effectively manage their parking supply. Consequently, the extent to which parkDC made it easier for drivers to find an available parking space, reduced congestion and pollution, improved safety, and encouraged use of other transportation modes were fundamental questions for the pilot evaluation.

In summary, the parkDC pilot team successfully developed a cost-effective, data-driven program. The pilot addressed parking problems for system users and DDOT through strategically applied data and a thoughtfully structured program. The pilot's success indicates that demand-based parking pricing programs can be applied effectively and sustainably, even in crowded urban environments and with fewer costly physical assets than have been deployed by other agencies. This chapter is organized into two areas of evaluation:

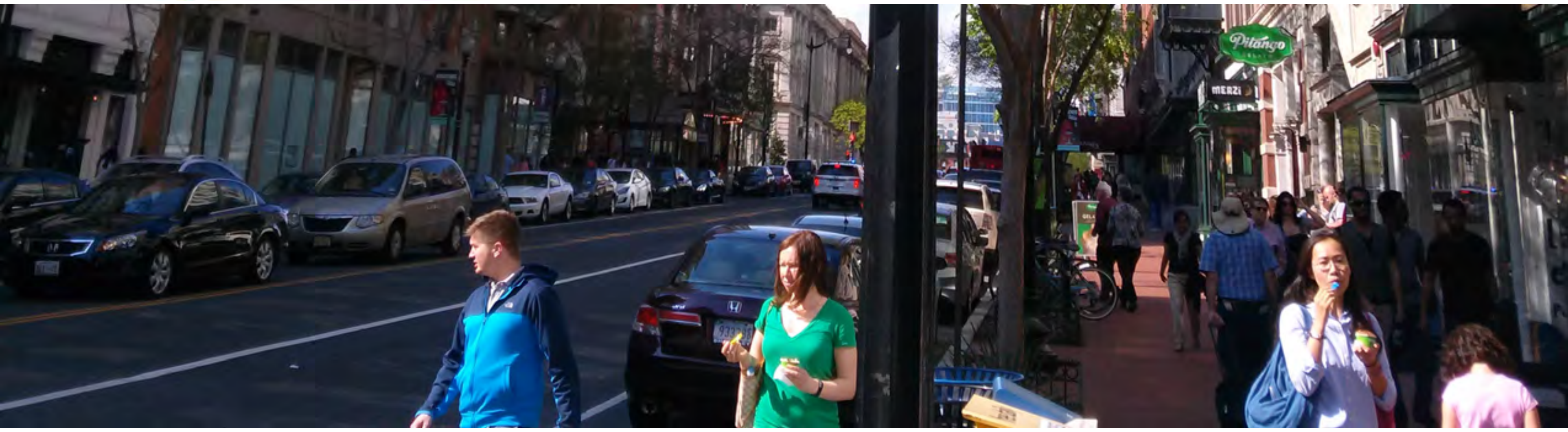
1 The user experience

The user experience is further divided into three levels: impacts felt by people parking in the area (level 1), impacts for those traveling in or through the area (level 2), and impacts on economic and multimodal activity (level 3):

- **Level 1: Curbside effects**. These outcomes are most directly tied to the pilot's parking pricing and policy changes. They include the pilot's influence on customer ability to find parking, duration of stay at a parking space, and instances of illegal parking.
- **Level 2: Pilot area network effects**. This includes the impacts on the surrounding transportation system, including the availability of parking information, placard use and abuse, and safety.
- **Level 3: Broader transportation and land-use activity.** This is the wider transportation ecosystem that included the parkDC pilot. Outcomes include broader transportation impacts on multimodal mobility and economic vitality.

2 The agency perspective

The agency perspective provides the outcomes experienced by DDOT, the managing agency of the parkDC Penn Quarter/Chinatown pilot.



Key findings are highlighted below and throughout this chapter to help the reader more easily identify key information and outcomes from the pilot.

Key Findings

The parkDC pilot met many of its goals and objectives. This was despite several external factors that would have been expected to increase demand for parking, including increases in local economic activity and automobile ownership and a sharp decrease in regional transit use.

- Across five price changes, the parkDC pilot decreased rates on 7% of all block faces, increased rates on 31%, and maintained existing prices on 63%. Average meter rates rose 32% from $2.30 to $3.03. In total, the number of block faces where demand matched supply increased by 16% between the first and last price changes.
- A conservative approach to price changes allowed the parkDC team to increase meter rates and effectively manage parking without aggravating users. Fewer than 1% of all block faces (five total) jumped more than two price bands during a price change; fewer than 1% (three total) that decreased to the lowest available rate and had to be increased during the following price change; and 100% that were increased to the highest available rate did not need to be decreased during the following price change.
- Automated data indicated average time to find parking was reduced by two to three minutes per trip. This was consistent with self-reported time to find parking, which dropped throughout the pilot, from close to 18 minutes before the first price change, to less than 12 minutes after the fifth price change. Correspondingly, the time vehicles spend circling for parking decreased by between 7% and 15%, depending on the time of day.
- After the parkDC team extended parking time limits on 22 low-demand block faces (24% of the pilot area) on weekday evenings and Saturdays, these block faces experienced a 12% increase in occupancy and a 14-minute increase in length of stay during weekday evenings. The average length of stay per vehicle decreased by three minutes throughout the entire pilot area.
- Average observed double parking decreased during the pilot, and citations for double parking went down throughout the pilot period.
- To reduce double parking in loading zones, DDOT applied demand based pricing at loading zones during and extended loading zone hours of operation. The number of minutes vehicles were observed double parking in loading zones decreased following DDOT's loading zone adjustments.

Key Findings

- DDOT determined that unauthorized use of the motorcoach zone was insignificant and did not make any changes to the motorcoach zone's pricing or operations.
- Average placard use decreased by 14.3% in the pilot area, versus 9.7% in the control area

5.1 THE SYSTEM USER EXPERIENCE

This section discusses the impacts felt by people parking in the area (level 1), those traveling in or through the area (level 2), or the area's businesses and the wider transportation ecosystem (level 3).

5.1.1 Level 1: Curbside Effects

This first level addresses the more direct outcomes of DDOT's changes to curbside policy. Outcomes include the pilot's influence on customer ability to find parking, duration of stay at a parking spot, and instances of illegal parking. This section is informed by curbside data collected before the first price change (October 2015) and after each successive price change.

Key Findings

- The number of block faces at equilibrium increased by 31% between the first and last price changes.
- The low-demand area with increased time limits during evenings and weekends experienced a 12% increase in occupancy and the length of stay increased 14 minutes during weekday evenings.

5.1.1.1 PARKING AVAILABILITY INCREASED ON HIGH-DEMAND BLOCKS, UNDERUTILIZED SPACES FOUND MORE TAKERS

The parkDC pilot price changes influenced demand and parking behavior. Changes in occupancy drove price adjustments and increases in the number of blocks staying at the same price show how the changes helped nudge block face occupancy to equilibrium (between 70% and 90%). Table 5-1 shows price changes across all five rate changes and highlights that the number of blocks nearing equilibrium increased over the course of the pilot. In total, the number of block faces at equilibrium increased by 31% between the first and last price changes.

Table 5-1. parkDC progress over time

parkDC progress over time

Pilot Measure	Pre-Pilot	Round 1 October 2016	Round 2 February 2017	Round 3 May 2017	Round 4 August 2017	Round 5 November 2017
Number of Price Points	1	3	5	7	8	9
Increased Price	-	94 blocks	172 blocks	143 blocks	71 blocks	89 blocks
Steady Price	-	229 blocks	186 blocks	220 blocks	262 blocks	266 blocks
Decreased Price	-	48 blocks	13 blocks	8 blocks	38 blocks	16 blocks
Average length of stay M-F	63 min	66.1 min	63.9 min	60.3 min	60	60.9
Blocks at Equilibrium[1]	-	61.7%[2]	50.1%	59.3%	70.6%[3]	71.7%

[1]Near target occupancy; no change recommended

[2]Conservative approach to first round price changes

[3]Higher percentage not changed due to construction

DDOT was able to observe the effects of each block-level price change on motorist behavior and parking occupancy. Figure 5-1 shows price changes between the fourth and fifth price changes by time band. While block faces that hold constant have exhibited occupancy rates near the established target, those with increased or decreased prices require additional pricing incentives to induce motorists to changes their behavior.

Figure 5-1. Round Five price changes

The parkDC pilot also aimed to improve turnover of high-demand parking spaces by encouraging shorter vehicle stays. By the fifth price change, the average vehicle length of stay in the pilot area had decreased by three minutes compared to pre-pilot conditions (Figure 5-2). Overall, this is a positive result for a generally high-demand area like the Penn Quarter/Chinatown pilot area. However, because the pilot area did have low-demand blocks for some areas during certain times, this measure alone is too simplistic to use in describing the impacts of the pilot on curbside space and should be considered within the context of the other findings.

DDOT also assessed trends in occupancy and length of stay to understand if and how length of stay differed between low and high occupancy block faces. Figure 5-2 shows how the relationship between occupancy and length of stay has evolved between price changes. After the first price change (top-left chart), low-occupancy block faces experienced an increase in occupancy and length of stay (blue trendline). Block faces at target occupancy experienced slightly less pronounced increase in occupancy and length of stay (green trend line). High-occupancy block faces experienced a decrease in occupancy and length of stay (red trend line).

Occupancy and length of stay trends stayed relatively consistent for low-occupancy block faces and target occupancy block faces between the first and fourth price changes. High-occupancy block faces, on the other hand, experienced an increase in occupancy and length of stay following the second price change, third price change, and fourth price change (top-right, bottom-left, and bottom-right charts, respectively). Following the fourth price change, high-occupancy block faces experienced slightly less marked increases in occupancy and length of stay than in previous price changes. This is likely due to the implementation of higher prices on high-occupancy blocks and time limit changes on low-occupancy blocks, discussed in greater detail below.

Figure 5-2. Occupancy Comparison to Length of Stay (Pre-Pilot to Fourth Price Change)

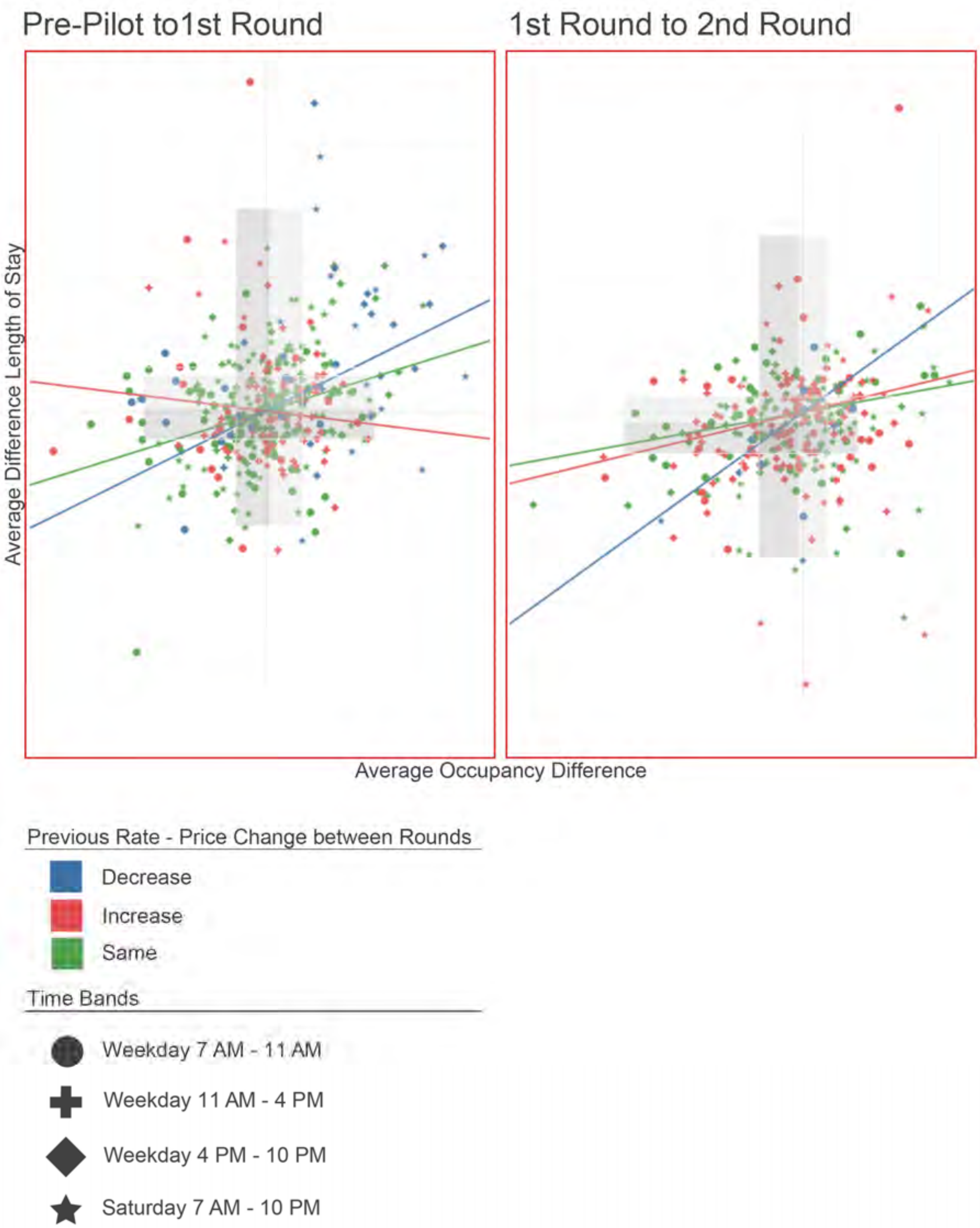
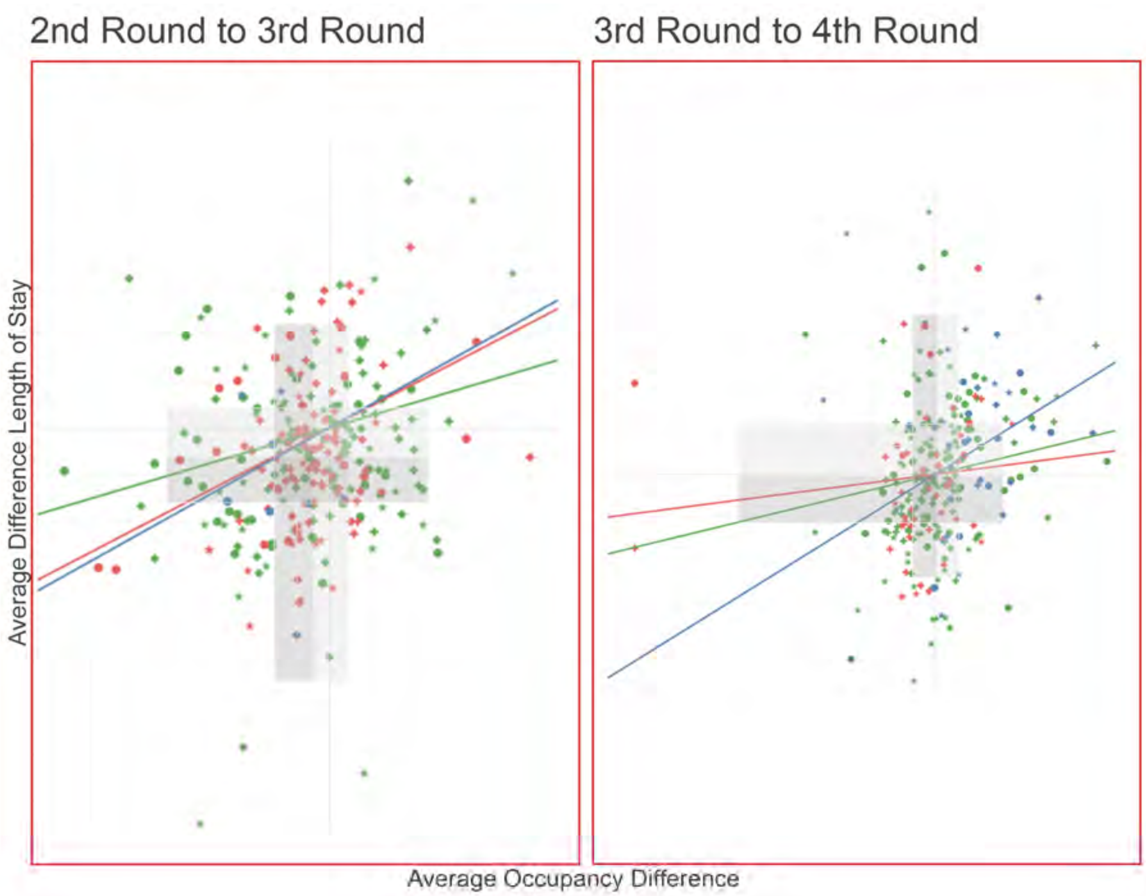


Figure 5-2. Occupancy Comparison to Length of Stay (Pre-Pilot to Fourth Price Change) (Continued)



Graphs show where block faces by time band fall in terms of average difference in length of stay (vertical axis) and average occupancy difference (horizontal axis) between price changes.

Each point is block face during a time band, colored by the price change between rounds.

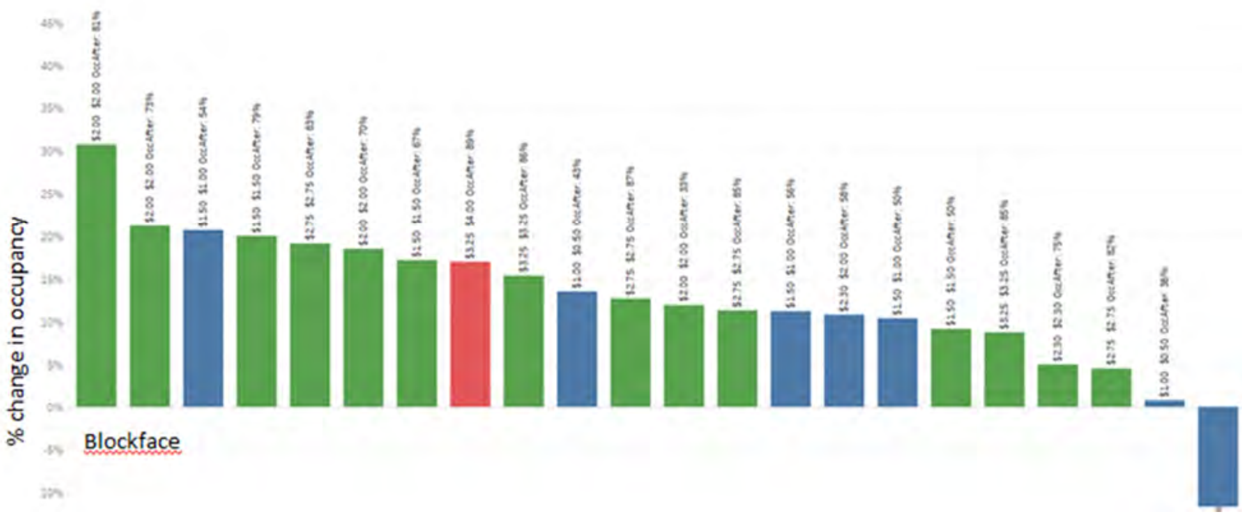
Colored lines show the trend line by rate change type (decrease, increase, steady).

The vertical shading shows the 25th to 50th percentile of difference in occupancy in light grey, and the 50th to 75th percentile of difference in occupancy in dark grey.

The horizontal shading shows the 25th to 50th percentile of difference in occupancy in light grey, and the 50th to 75th percentile of difference in occupancy in dark grey.

DDOT also tested the influence of time limit changes on customer behavior. During the fourth price change, time limits at low occupancy blocks in the eastern third of the pilot area were increased to incentivize parking during the weekday evenings and on Saturdays. These blocks experienced a 12% increase in occupancy and the length of stay increased 14 minutes during weekday evenings. Figure 5-3 shows the block faces that experienced increases in activity due to extended time limits.

Figure 5-3. The impact of time limit changes on parking occupancy between the 4th and 5th price changes (Weekday, 4 PM – 10 PM)



5.1.1.2 CUSTOMERS SPENT LESS TIME FINDING A PARKING SPACE

DDOT used three approaches to estimate parking search times - automated parking search time (AVI) data, manual bike survey data, and customer feedback - to understand how the parkDC pilot influenced the time it took customers to find a parking space.

Key Findings

- Automated data indicated average time to find parking was reduced by two to three minutes per trip
- Manual surveys of the time to find parking with a limited sample size produced mixed results, which further highlighted the benefits of the automated data collection approach
- Customer-provided feedback suggests that the perceived time to find parking has decreased by seven minutes since the pilot was implemented

Source: Bruce Emmerling, pixabay

5.1.1.2.1 Time to find a parking space

A stated goal of the pilot was to reduce the time to find parking. Progress towards this goal can be measured by looking at the length of time of cruising trips. The length of time of cruising trips was identified by time of day[1] for weekdays and weekend days and partitioned by price change period (Figure 5-4 and Figure 5). As shown, the length of time spent finding an open parking space is down during all time periods on both weekends and weekdays. Average cruising times were reduced by two to three minutes per trip.

[1] Time bands for cruising analysis align with pilot time bands but further bisect the AM and PM Periods: Morning Rush: 7:00 - 9:30 AM; Mid-Morning: 9:30 - 11:00 AM; Mid-day: 11:00 AM - 4:00 PM; Afternoon Peak: 4:00 - 6:30 PM; Evening: 6:30 - 10:00 PM

Figure 5-4. Weekday Cruising Trip Times

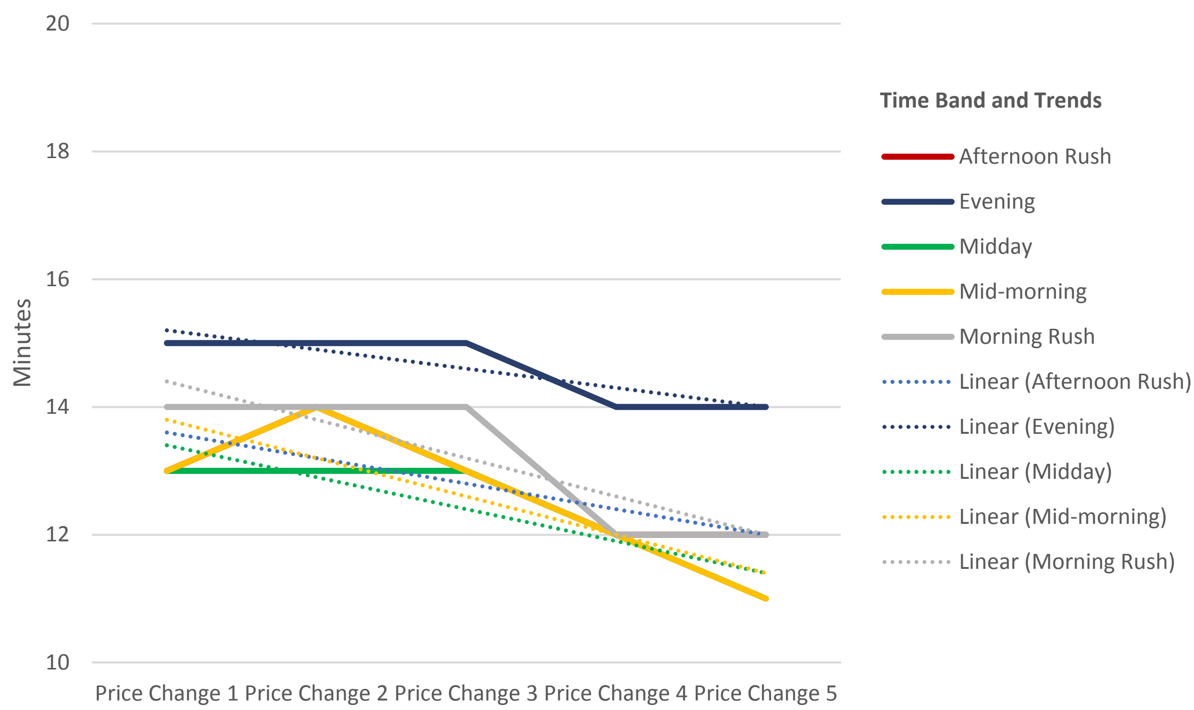
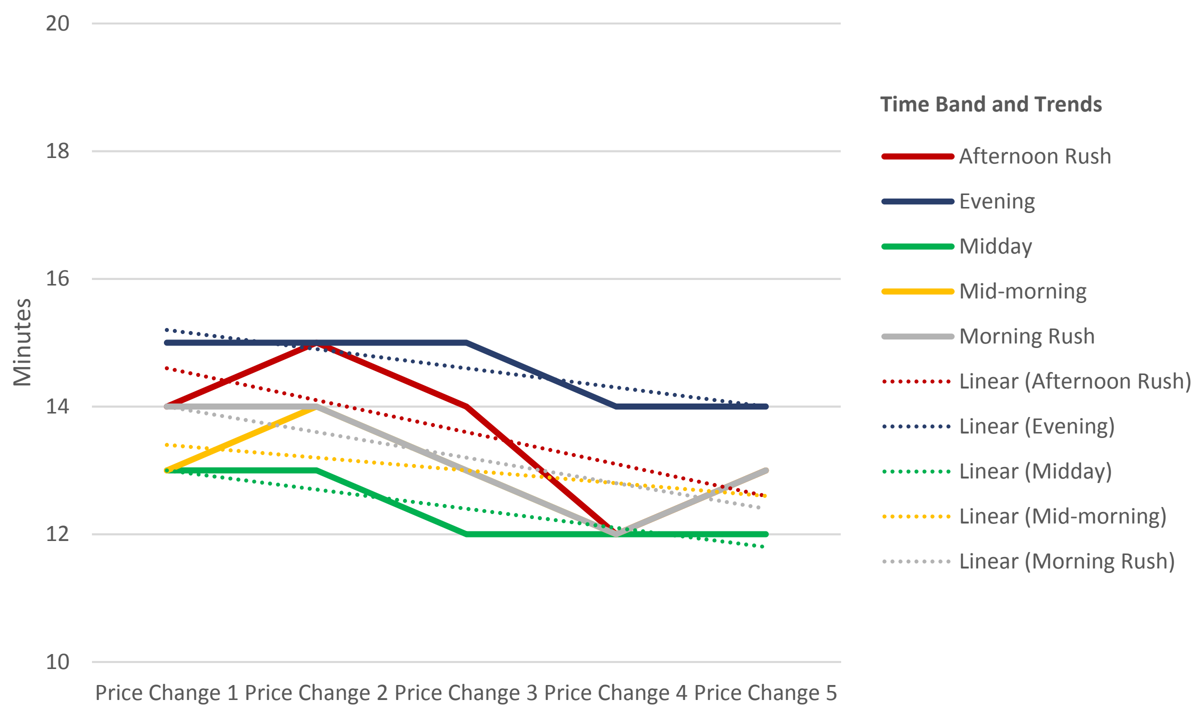


Figure 5-5. Weekend Cruising Trip Times



5.1.1.2.2 Manual Parking Search Times

In addition to assessing parking search time using AVI data, DDOT collected time-to-find parking data using manual bike surveys before and after pilot implementation to understand changes to the average time to find parking.

As shown in Figure 5-6 and Figure 5-7, the average weekday time to find parking increased in the morning and evening time periods (80% and 516% increases, respectively) but decreased by 25% in the midday time period in the pilot area. This is counter to the automated time to find parking data and inconsistent with the time to find parking in the control area, which dropped during all three time periods. It was later noted that the day used to collect the time to find parking data in the "after" time period coincided with a Janet Jackson concert at the Capital One Arena which likely skewed the after-data collection.

Figure 5-6. Changes in average weekday time to find parking

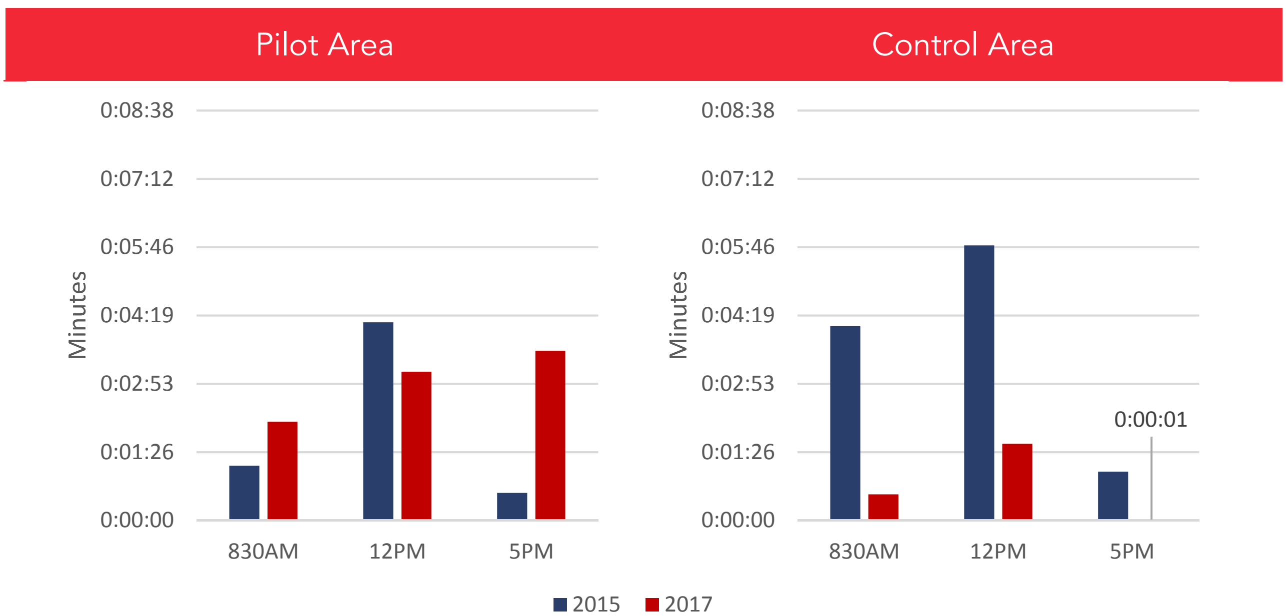
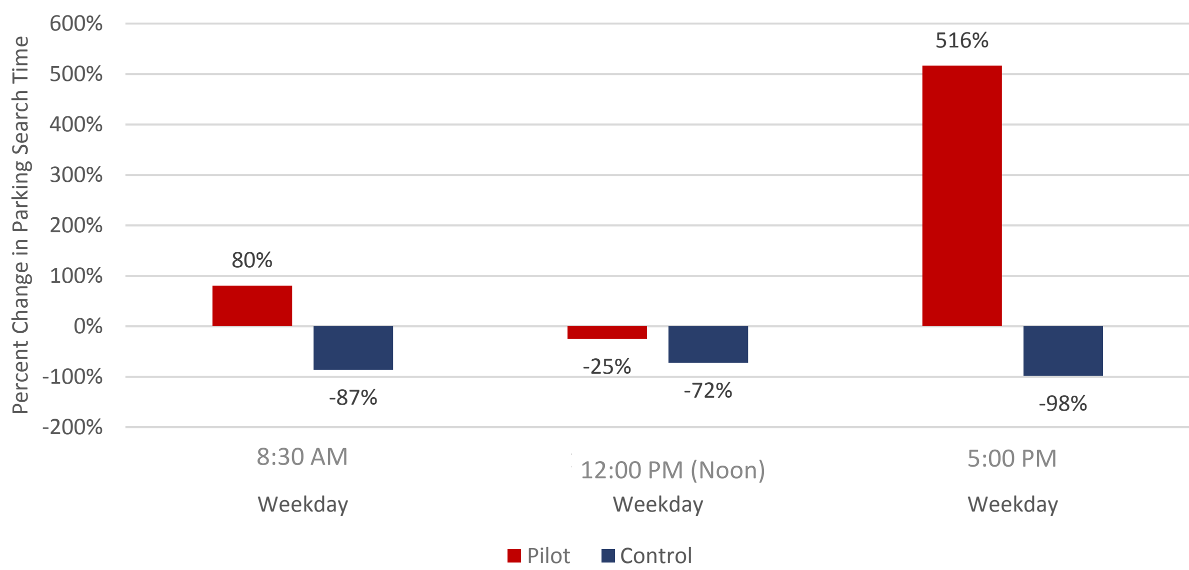


Figure 5-7. Percent change in average weekday time to find parking



As shown in Figure 5-8 and Figure 5-9 the average Saturday time to find parking increased in all time periods in both the pilot area and control area (78% to 147% increases observed in the pilot area, 55% to 85% increases observed in the control area). DDOT also assessed time to find parking on Sundays. As shown in Figure 5-8, the average Sunday time to find parking increased by almost six minutes or by 415% in the control area and remained high in the pilot area. Sunday parking is currently unregulated, suggesting that pricing and time limits help maintain lower weekday and Saturday parking search times.

Figure 5-8. Changes in average weekend time to find parking

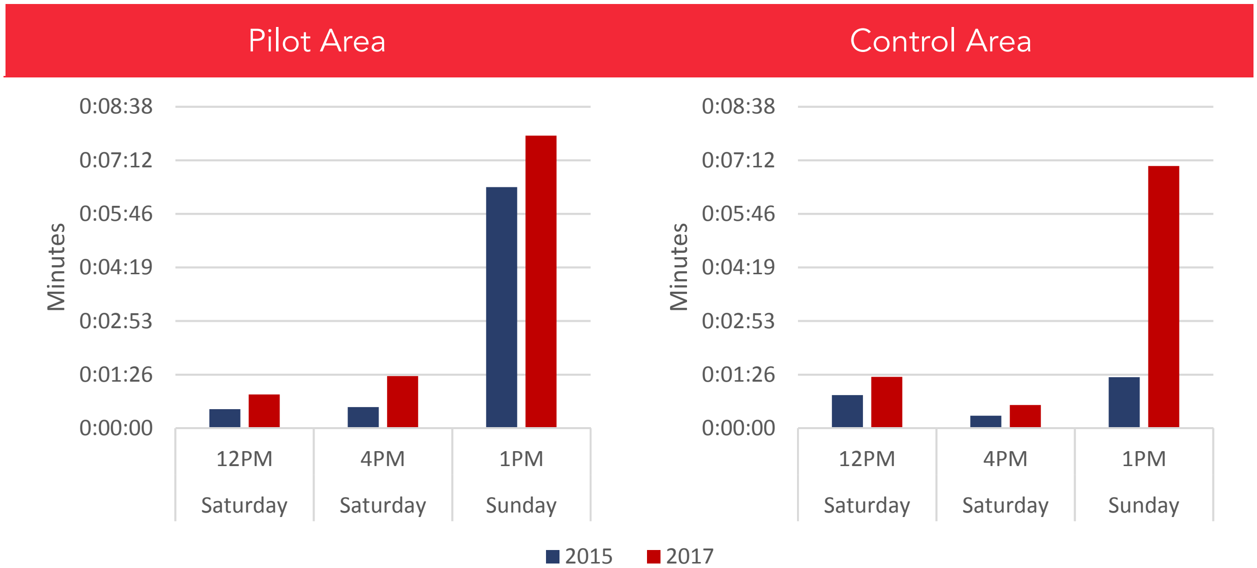
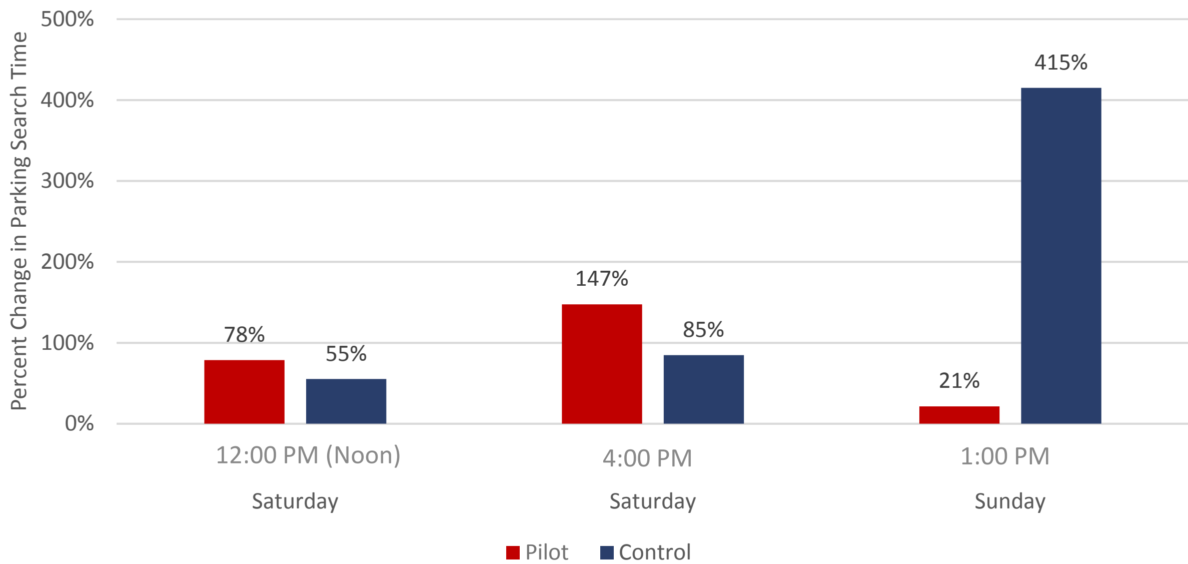


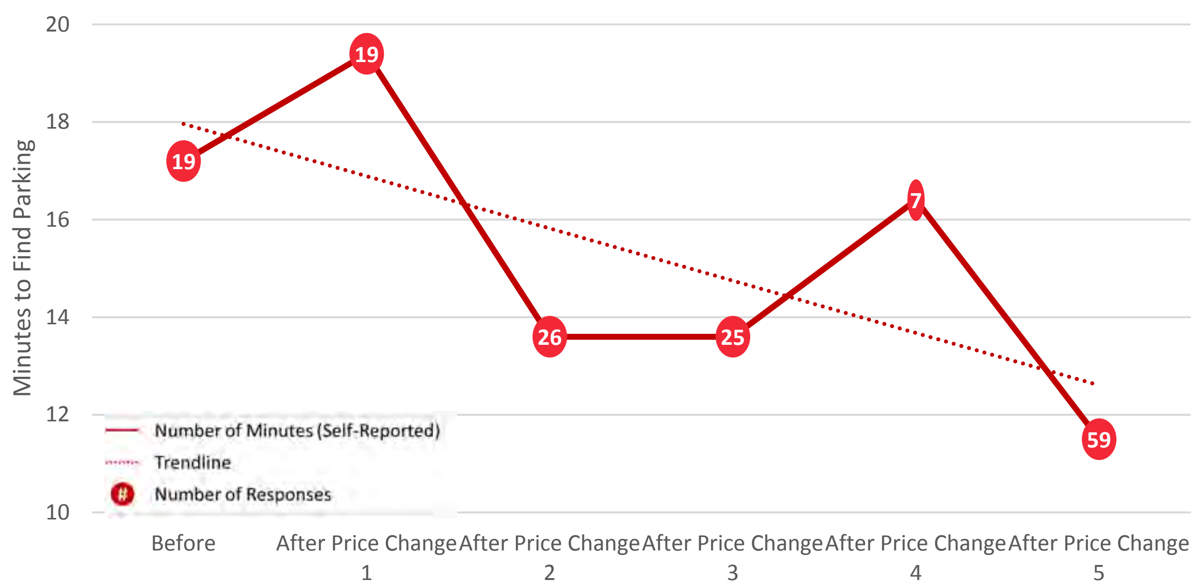
Figure 5-9. Percent change in average weekend time to find parking



Customer Feedback on Time Needed to Find Parking

DDOT collected customer feedback on the time needed to find parking before the pilot was implemented and throughout its duration. Based on customer feedback, the perceived time to find parking in the pilot area has decreased by seven minutes, suggesting that the parkDC pilot has helped improve the customer experience. Figure 5-10 shows how changes in perceived time to find parking have changed over time. As shown, the average self-reported time to find parking has dropped throughout the pilot, from close to 18 minutes before the first price change, to less than 12 minutes after the fifth price change. The self-reported data is consistent with the automated time to find parking data which showed similar reductions in the time to find parking.

Figure 5-10. Changes in perceived customer time to find parking



5.1.1.3 AS SUPPLY OPENED, DOUBLE PARKING DECREASED

Key Findings

- The pilot area experienced a 0.9% decrease in instances of double parking between the 2015 and 2017 studies, while the control area also saw decreases in double parking, albeit to a lesser extent (0.4% decrease).
- Double parking occurred at less than one percent of all parking spots in the pilot area during the 2017 round of data collection. As in 2015, the pilot area experienced lower levels of double parking than the control area in 2017.
- To reduce double parking in loading zones, DDOT increased loading zone prices during Price Change 4 in September 2017 and extended loading zone hours of operation in October 2017.
- DDOT determined that unauthorized use of the motorcoach zone was insignificant and did not make any changes to the motorcoach zone's pricing or operations.

Double parking is a strong symptom of high parking demand and low parking supply. To understand pilot impacts on double parking, DDOT conducted a before and after study to compare the change in instances when vehicles were observed double parking in both the pilot area and a control area, assessed double parking citation issuance, and conducted a before and after study to compare the number of minutes that vehicles were observed double parking at loading zones. Decreases in observed double parking, citations issued for double parking, and in the number of minutes that vehicles were observed double parking at loading zones all point to the positive impacts of DDOT's demand-based pricing pilot on parking supply and demand.

5.1.1.3.1 Double parking comparison: pilot versus control areas

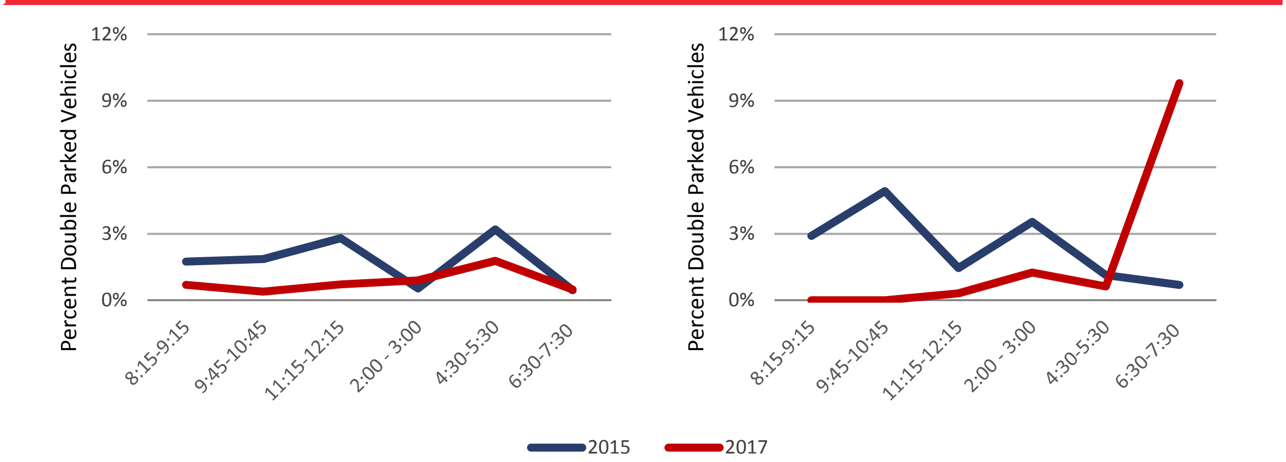
DDOT collected double parking data before and after pilot implementation in the pilot area and a control area. In the context of this analysis, double parking was defined as observed double parking vehicles as a percent of total curbside spaces in the pilot and control areas. Overall, the pilot area experienced a 0.9% decrease in instances of double parking between the 2015 and 2017 studies (Table 5-2). The control area also saw decreases in double parking, albeit to a lesser extent (0.4% decrease). While the parkDC pilot likely played a role in the increase in available parking spaces in the pilot area, observed decreases in double parking could also be due to reconfigurations of available on-street parking, improved access to alternative modes of transportation, and other external factors.

Table 5-2. Observed changes in average double parking

	Pilot Area	Control Area
	Average Double Parking	Average Double Parking
Before (2015)	1.8%	2.4%
After (2017)	0.8%	2.0%
Change over Time	-0.9%	-0.4%

Figure 5-11 shows how observed double-parked vehicles as a percent of total spaces changed throughout the day on weekdays between 2015 and 2017 in the pilot area and in the control area.

Figure 5-11. Weekday double parking rates in the pilot area (left) and control area (right)



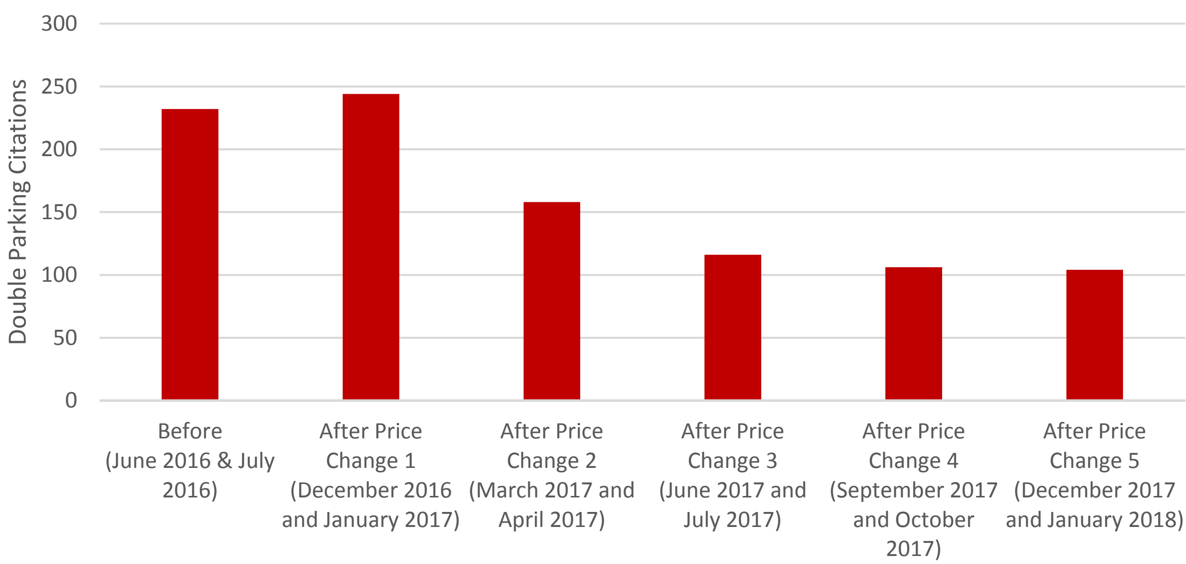
In the 2015 round of data collection (shown in blue), the highest levels of double parking were observed early in the mid-morning and evening peak periods, which coincided with competing demands for loading zones in both the control and pilot areas. 65% of vehicles observed double parking in the pilot area and 91% of vehicles observed double parking in the control area were commercial vehicles. Average daily double parking occurred at less than 3% of all parking spots in the pilot and control areas during the 2015 round of data collection. The pilot area experienced slightly lower levels of double parking than the control area.

The 2017 round of data collection (shown in red) found that double parking decreased in both the pilot and control areas. The highest levels of double parking were observed in the evening in the control area. Double parking occurred at less than one percent of all parking spots in the pilot area during the 2017 round of data collection. As in 2015, the pilot area experienced lower levels of double parking than the control area in 2017.

5.1.1.3.2 Double parking citations

Double parking instances are a proxy for indicating when a block is full. Consequently, the number of citations given for double parking can indicate the number of times blocks are full and serve as an indicator whether there is enough parking available to serve drivers. As shown in Figure 5-12, the number of double-parking citations initially stayed about the same after the first price change, and then continued to decrease as the pilot progressed. However, as previously indicated in Chapter 3, this decrease may have also been the result of inconsistent enforcement, and therefore no conclusions can be drawn from this data.

Figure 5-12. Double parking citations during the pilot period



5.1.1.3.3 Double parking in loading zones

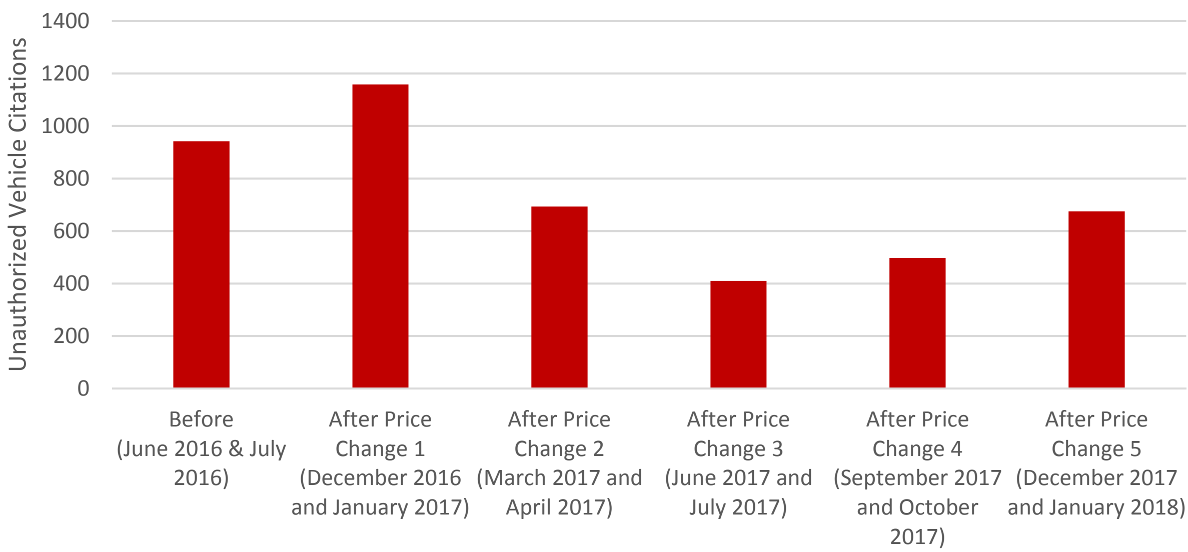
Additional loading zone data was collected in January 2018 so DDOT could assess the results of its loading zone strategies implemented during the fourth price change in September 2017 (increased loading zone prices) and October 2017 (extended loading zone hours of operation). Using time-lapse camera footage, DDOT found that while the number of unique instances of double parking increased by 13% after prices increased, the number of minutes vehicles were observed double parking in loading zones decreased by 43% (Table 5-3). More follow-up data is needed, however, because of the relatively small sample size and several outliers, particularly on the 500 block of 10th Street NW, which does not allow paid parking and therefore did not have parking regulations or price changes. DDOT intends to build on the preliminary findings from the parkDC pilot to grow its loading zone pricing and enforcement program, recognizing that a robust program has the potential to reduce instances of double parking and shift delivery and other commercial trips to off-peak periods.

Table 5-3. Minutes vehicles were observed double-parked at loading zones

Location	Minutes Before (August 2017)	Minutes After (January 2018)	Percent Change
504 10th Street NW	463.7	5.0	-99%
511 10th Street NW	398.6	100.0	-75%
905 E Street NW	125.0	80.0	-36%
501 G Street NW	110.0	115.0	+5%
977 F Street NW	30.0	40.0	+33%
1006 E Street NW	20.1	40.0	+99%
755 8th Street NW	15.0	20.0	+33%
777 7th Street NW	15.0	225.0	+1400%
650 F Street NW	5.0	45.0	+800%
Total Minutes	**1182.4**	**670.0**	**-43%**
Average	131.4	74.4	

In addition to the time-lapse camera footage, DDOT also reviewed the number of citations given in the pilot area to unauthorized vehicles in a loading zone. However, inconsistent enforcement in the pilot area during the pilot made it impossible to draw conclusions from the citation data. The number of citations for unauthorized vehicles in a loading zone is provided in Figure 5-13.

Figure 5-13. Citations for unauthorized vehicle in a loading zone



5.1.1.3.4 Double parking in a motorcoach zone

DDOT recognized that high tourist demand in the Chinatown and Penn Quarter neighborhoods could possibly result in tour buses illegally parking or idling in travel lanes, temporarily diminishing the capacity of the pilot area's busy streets. As part of the preliminary loading zone analysis conducted in 2016, DDOT sought to identify if there was a clear issue with non-motorcoach vehicles parking illegally in the single motorcoach zone located on 10th Street NW. The team planned to modify pricing in the motorcoach zone if substantial unauthorized use of the motorcoach zone was evident. The 2016 study revealed that the motorcoach zone experienced some of the lowest levels of unauthorized use by passenger vehicles compared to other loading zones in the pilot area. Seventy-nine percent of vehicles recorded in the loading zone were motorcoach vehicles (Table 5-4). Motorcoaches occupied the motorcoach zone for 41% of the full study period, unauthorized vehicles utilized the motorcoach zone for 10% of the full study period, and the motorcoach zone stood empty for 46% of the full study period.

Based on the results of the 2016 analysis, DDOT determined that unauthorized use of the motorcoach zone was insignificant and did not make any changes to the motorcoach zone's pricing or operations. Outside of the motorcoach zone in the broader pilot area and other sites in the District frequently visited by tourists, motorcoach idling is routinely observed. To address motorcoach idling across the District, DDOT decided to advance other initiatives separate from this pilot.

Table 5-4 Motorcoach zone utilization (2016)

Number of Vehicles			Average Length of Stay		
Passenger Car	Commercial Vehicle	Bus	Passenger Car	Commercial Vehicle	Bus
22	10	120	8 min	22 min	15 min

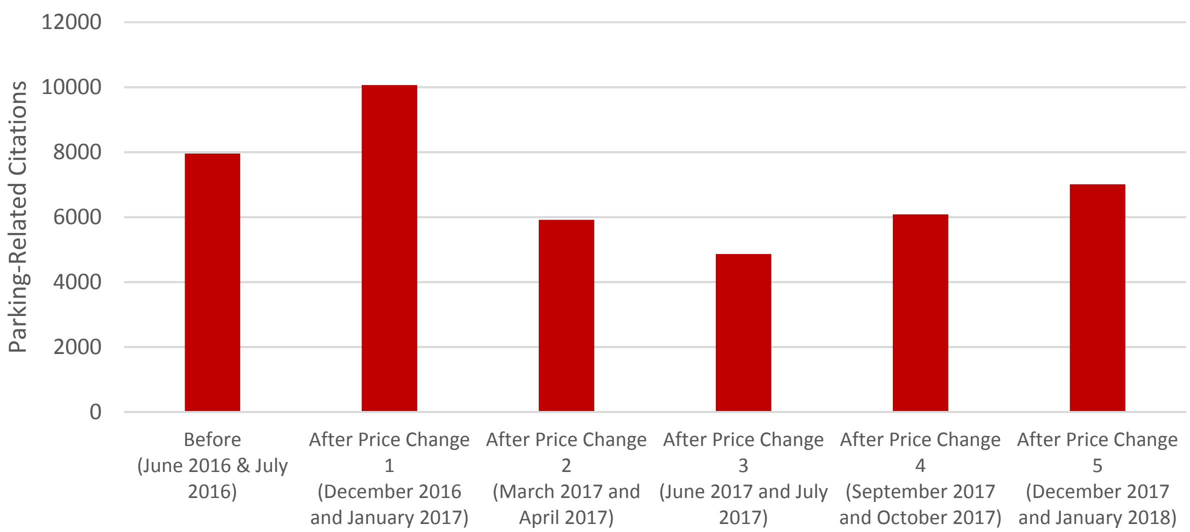
Vehicle Occupancy			Total Time of Vehicle Occupancy			
Passenger Car	Commercial Vehicle	Bus	Passenger Car	Commercial Vehicle	Bus	Vacant
14%	7%	79%	5%	5%	41%	46%

KEY: Passenger Car; Commercial Vehicle; Bus; Vacant

5.1.1.4 PARKING ENFORCEMENT

Based on findings from other performance parking initiatives, in particular SF*park,* DDOT expected the increased availability of open parking spaces to reduce the temptation to park illegally, resulting in fewer parking violations. As shown in Figure 5-14, the total number of parking-related citations given (not including failure to display receipt infractions, discussed later) initially increased from around 8,000 to approximately 10,000 after the first price change, but then decreased to between 5,000 and 7,000 over the next three price changes., While these findings lined up with expectations, no conclusions can be drawn from this data due to the inconsistent enforcement assumed to have occurred based on citation numbers and citation types issued throughout the duration of the project.

Figure 5-14. Total parking-related citations given during the pilot period*



*This chart excludes citations for failure to display the meter receipt because these were incorrect citations in the pilot area's pay-by-space configuration.

5.1.1.5 PAY-BY-SPACE MAKES PARKING SPACES EASIER TO FIND

The transition to a demarcated, pay-by-space environment proved effective for DDOT and customers. As detailed in Chapters 3 and 4, the demarcation of parking spaces impacts perception and the efficient use of limited available parking spaces. While no specific data was collected for this, it is expected that because customers can park more efficiently in a demarcated environment, this configuration likely contributed to making it easier to find a parking space.

5.1.2 Level 2: Pilot area Network Effects

This includes the surrounding transportation system, and impacts reported include the availability of parking information, placard use and abuse, and safety. This section is informed by curbside data collected before the first price change (October 2015) and after each successive price change.

5.1.2.1 CRUISING FOR PARKING DECREASED IN THE PILOT AREA

Key Findings

- Vehicle cruising rates generally decreased throughout the duration of the pilot

In the context of this analysis, the cruising rate is defined as the percentage of vehicles searching for parking. There are several objectives behind this analysis. DDOT wanted to understand the proportion of vehicles cruising for parking, identify where in the network cruising activity is occurring, and understand shifts in cruising rate patterns based on time of day. The number of cruising and non-cruising trips were identified by time period for weekdays and weekend days and partitioned by price change period. As shown in Figure 5-15 and Figure 5-16, the percentage of vehicles cruising for parking within the pilot area is consistently between 20% and 40% depending on the time of day and price change period. However, trendlines for most times of day showed decreasing cruising rates, with two exceptions. First, cruising rates stayed relatively steady during the “afternoon rush” on both weekends and weekdays, which may reflect the restricted supply of parking due to rush hour parking restrictions on weekdays. Second, the trendline for weekday midday cruising was slightly up; this time of day has also had the largest share of price increases as blocks were not able to reach equilibrium. The seasonality of activity in the pilot area is also visible in the cruising trends, with higher activity in the fall and early winter after price changes 1 and 5.

A more in-depth review of the data identified areas with heavy cruising, which include 7th Street between the National Portrait Gallery and the Capital One Arena. Cruising intensity near the intersections of 9th Street and G Street NW and the 9th Street and F Street NW remains high throughout the day. Further, cruising is noticeable around the National Building Museum (from 4th to 6th streets and F to G streets), with cruising intensifying as the day progresses.

Figure 5-15. Weekday Cruising Rates

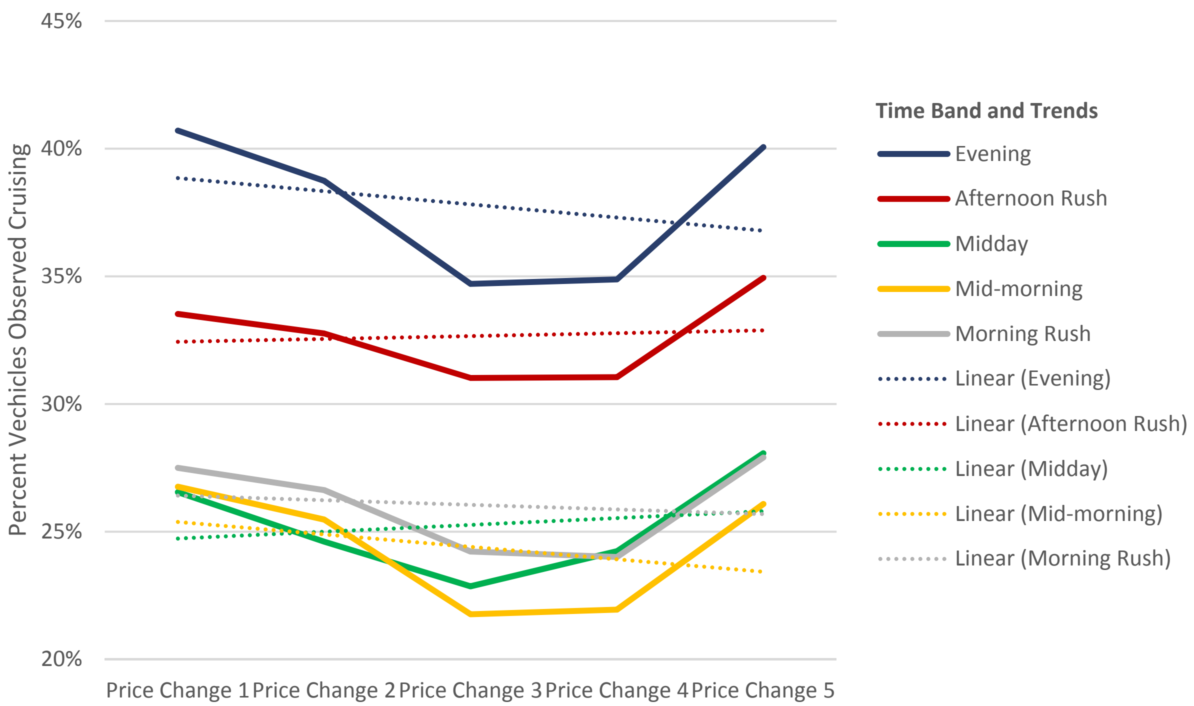
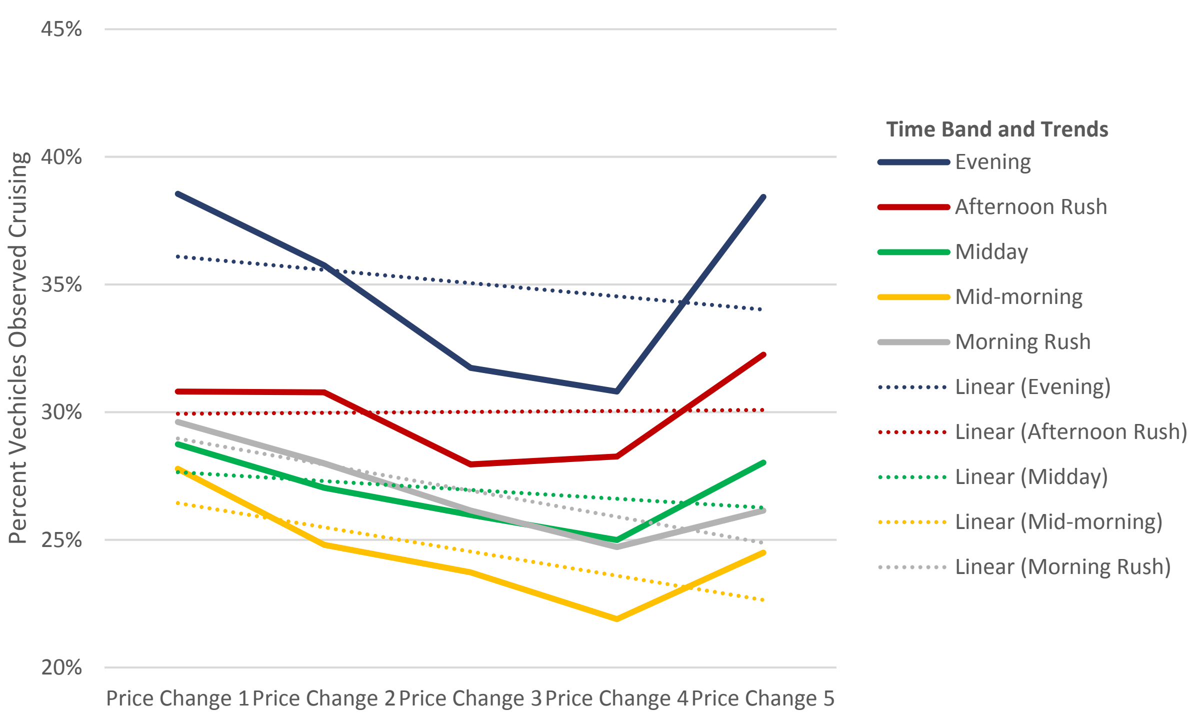


Figure 5-16. Weekend Cruising Rates



5.1.2.1.1 Cruising Contribution to Vehicle Miles Traveled

While the cruising rate tells us what percent of trips are searching for parking, it does not consider the length of trips. The contribution of cruising to total area VMT can account for varying trip lengths. Given that cruising vehicles would be expected to have longer trips within the pilot area as they circled around searching for parking, improved parking availability would be expected to reduce cruising trip lengths and therefore total cruising VMT.

The share of total observed VMT due to cruising trips was identified by time of day for weekdays and weekend days and partitioned by price change period (Figure 5-17 and Figure 5-18). As shown, the percentage of vehicle miles that cruising contributes to the pilot area VMT is consistently between 40% and 60% depending on the time of day and price change period. As expected, the cruising vehicle's share of VMT is higher than their share of total trips. Also noticeable is that on weekdays, except for the "evening," the total cruising contribution trendline was down. On weekends, cruising's contribution to VMT was up during the "evening" and "afternoon rush" time periods, but down for the other three time periods.

Figure 5-17. Weekday Cruising Contribution to VMT

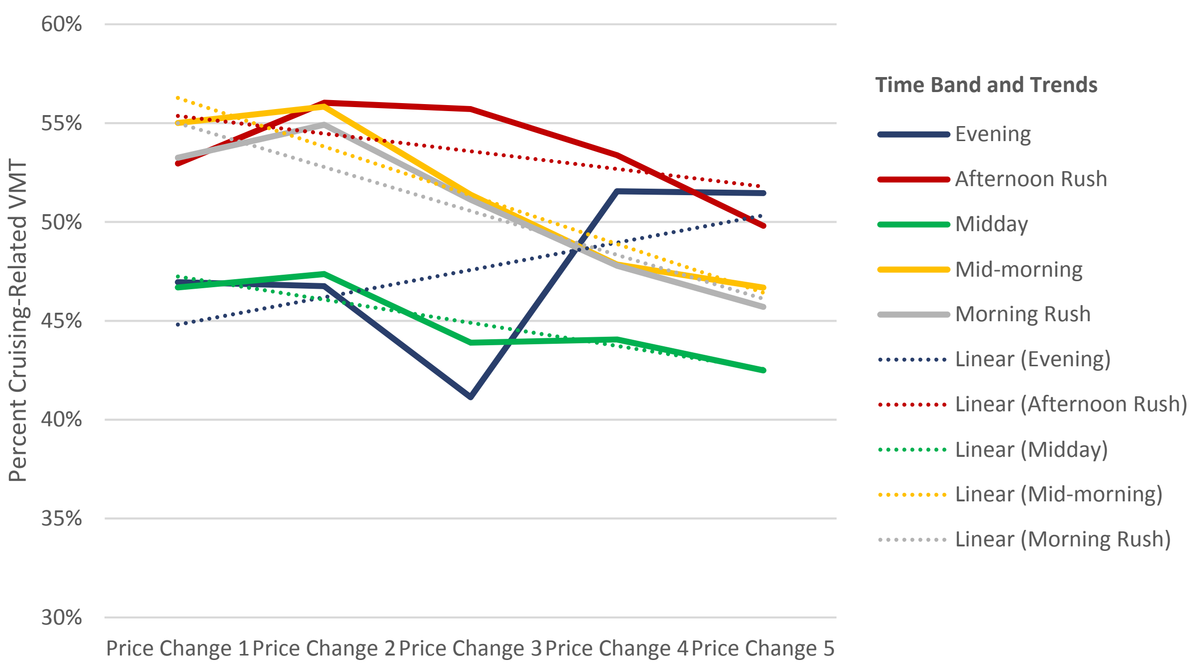
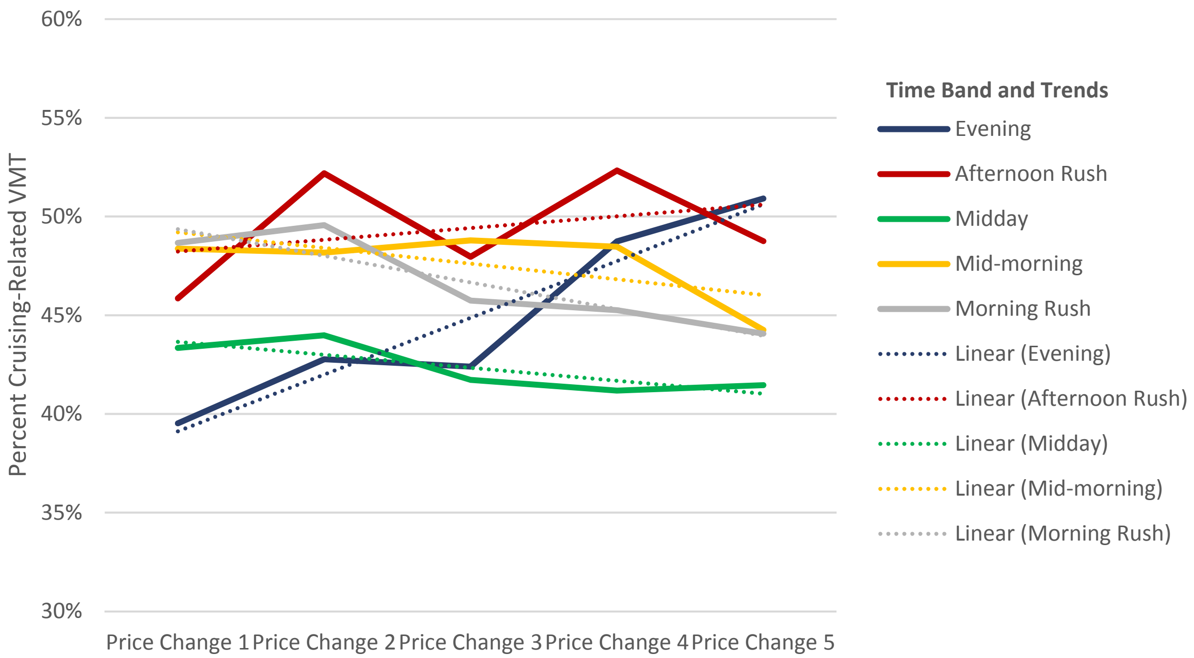


Figure 5-18. Weekend Cruising Contribution to VMT



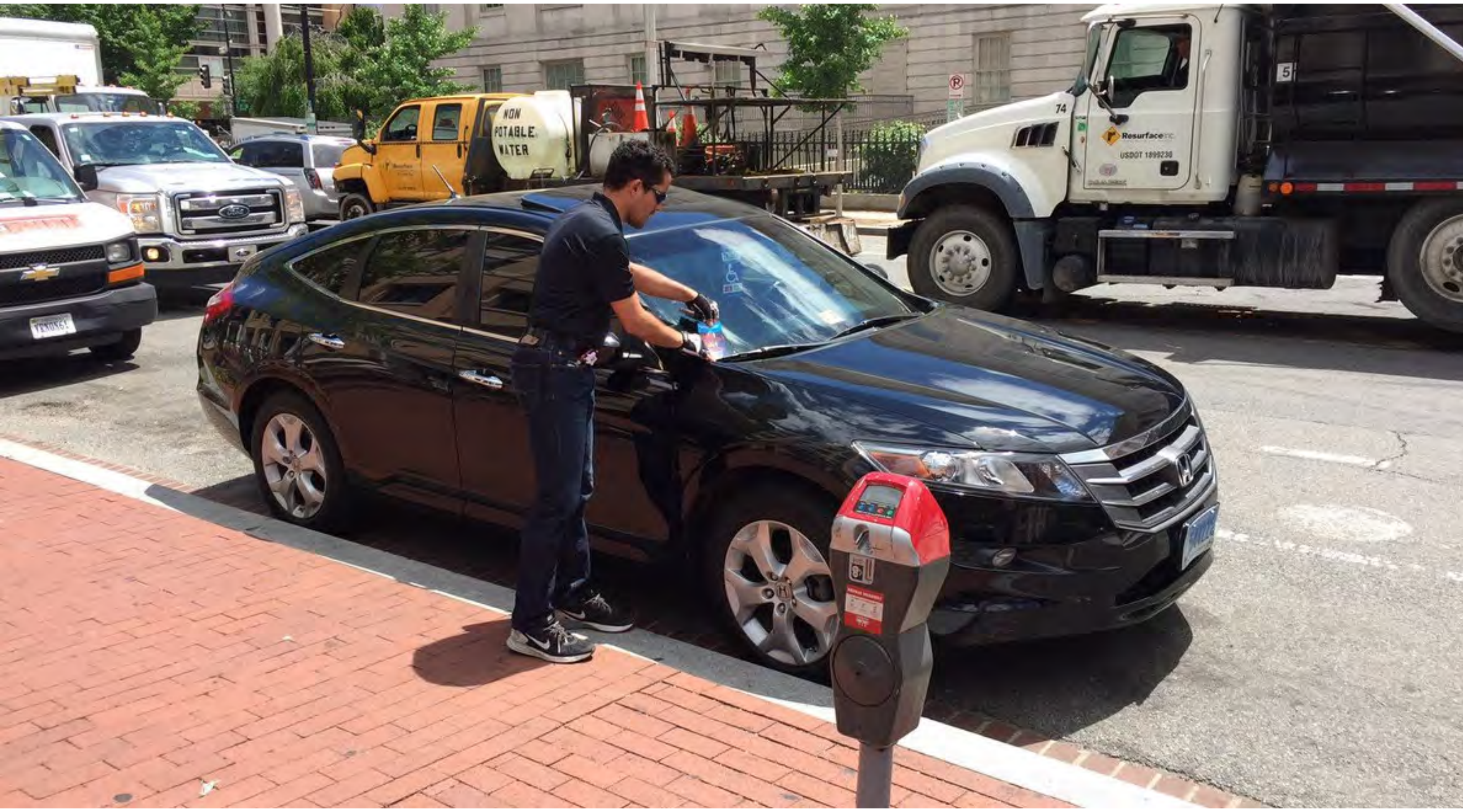
Source: Wikimedia Commons, Another Believer

5.1.2.2 AVAILABILITY OF PARKING INFORMATION

Key Findings

- An ongoing survey showed an increase in the percentage of customers who think that parking regulations and pricing are clear and easy to understand.

DDOT's cost-effective, data-driven approach to demand-based pricing enabled the agency to increase the abundance and accessibility of parking information. Two mobile applications (described in Chapter 5) provide real-time estimates of parking availability. New parking signs and calendar-style decals on parking meters (also described in Chapter 5) more clearly conveyed information about when customers could park and how much parking would cost. An ongoing survey (described in Section 0) showed an increase in the percentage of customers who think that parking regulations and pricing are clear and easy to understand.



5.1.2.3 PLACARD USE

Key Findings

- In 2017, average placard use decreased by 14.3% in the pilot area, and 9.7% in the control area.

The 2015 round of data collection indicated motorists were consistently using placards to occupy curbside parking spaces. In the pilot area, placard use peaked just above 35% in the midday time period before declining into the evening time period (Figure 5-19). The pilot area experienced slightly higher levels of placard use than the control area.

In 2017, average placard use decreased by 14.3% in the pilot area, and 9.7% in the control area (Table 5-5). While placard use in the pilot area exceeded placard use in the control area in 2015, placard use in the control area exceeded placard use in the pilot area in 2017, though the two areas had much more similar usage rates in 2017. 2017 placard use in the pilot area stayed relatively consistent throughout the day, while placard use in the control area continued to experience sharper peaks (Figure 5-19). The overall decrease in use indicates that placard users are likely now paying for parking or there has been an increase in curbside availability for paying customers.

While the changes in placard use cannot be directly tied to the parkDC pilot, DDOT identified a few factors that may have affected use. The implementation throughout the central business district of Red Top accessible parking meters made long-term and free on-street parking unavailable (and illegal) to a high number of placard holders. DDOT also conducted outreach to law enforcement and government placard users to discourage placard use, which may also have contributed to the decline in placard use. However, DDOT did not collect detailed data on the types of parking placards observed in the before and after studies. Because of this oversight, DDOT could not make specific observations about trends in placard use based on placard user type (i.e., disabled placard holders vs. government placard holders).

Figure 5-19. Average Weekday Placard Use (Red Top Meters Deployed May 2017)

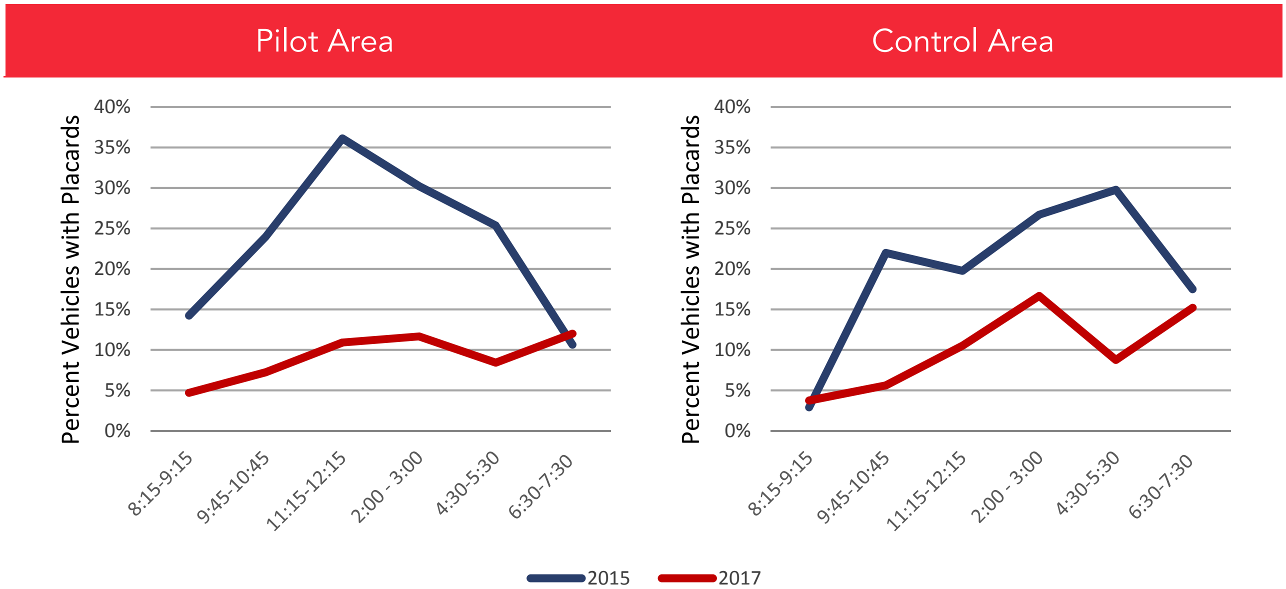


Table 5-5. Observed changes in placard use

	Pilot Area	Control Area
	Average Placard Use	**Average Placard Use**
Before Red Top Meters Deployed (2015)	23.4%	19.8%
After Red Top Meters Deployed (2017)	9.2%	10.1%
Change over Time	-14.3%	-9.7%

5.1.2.4 SAFETY

Vehicles competing for limited on-street parking spaces tend to circle for parking, contributing to downtown congestion and safety concerns associated with erratic or unpredictable motorist behavior. Although detailed safety data were not available for analysis during the pilot implementation period, the pilot's role in making it easier to find and pay for parking likely resulted in more predictable motorist behavior and fewer erratic movements.

5.1.3 Level 3: Broader Transportation and Land-Use Activity

This is the wider transportation ecosystem that included the parkDC pilot. Outcomes include broader transportation and land use activity and impacts on multimodal mobility and economic vitality.

The urban core of the District, including the Penn Quarter/Chinatown neighborhoods, is affected by changes to the transportation system both locally and region-wide. While changes, both temporary and permanent, tend to reverberate regionally, they have especially large and compounding impacts in the District and the urban core.

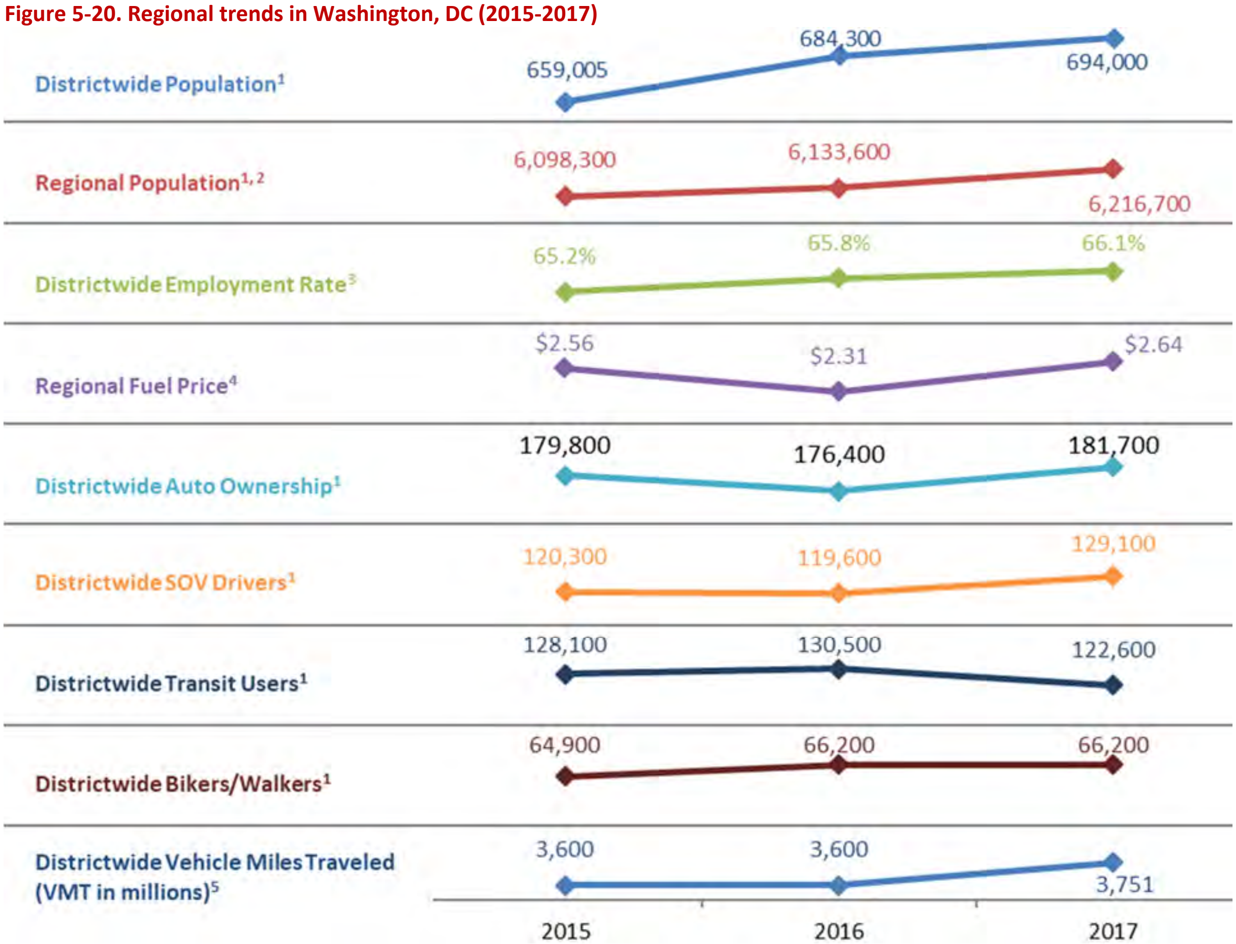
5.1.3.1 DISTRICTWIDE TRENDS

Key Findings

- In most cases, trends in the pilot area aligned with Districtwide trends: both saw an increase in population, automobile ownership, and biking and walking to work.
- In contrast to a Districtwide upward trend in single occupancy vehicle drivers, the pilot area saw a downward trend in single-occupancy vehicle drivers.

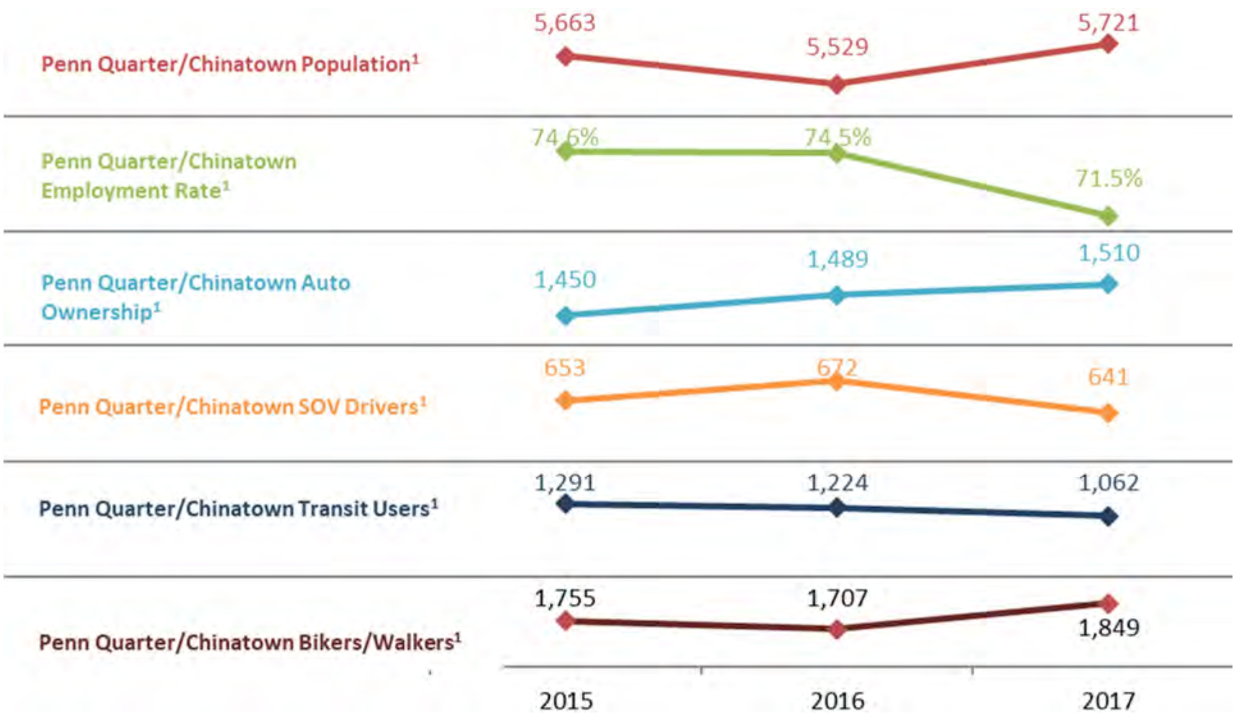
Changes to the District's population, employment, travel demand, economic activity, and multimodal transportation network can influence parking demand in the District, including the areas studied in the parkDC pilot. As shown in Figure 5-20, increases in auto ownership and single-occupancy vehicle (SOV) drivers among District residents from 2015 to 2017 suggest an increase in District-based parking demand during the pilot period. However, changes in regional travel patterns, population, employment, non-motorized travel, and fuel price may have offset these trends.

Figure 5-20. Regional trends in Washington, DC (2015-2017)



[1]American Community Survey 1-Year Estimates
[2]Washington-Arlington-Alexandria Metropolitan Statistical Area
[3]Bureau of Labor Statistics
[4]U.S. Energy Information Administration
[5]FHWA Office of Highway Policy Information

Figure 5-21. Trends in the parkDC pilot area (2015-2017) – values represent Penn Quarter/Chinatown residents only



[1]American Community Survey 5-Year Estimates

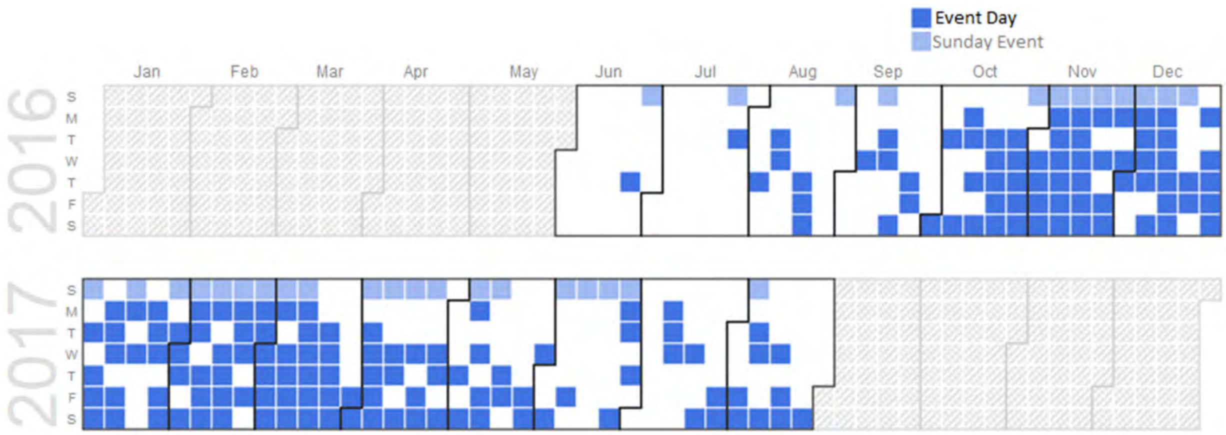
Most regional and pilot-area-specific trends observed during the pilot are likely related to external influences. DDOT has considered and investigated a range of external factors that could be influencing parking demand in addition to price changes, including:

- **Metro Activity and SafeTrack:** WMATA's SafeTrack program implemented long-duration track outages for major safety projects in key parts of the Metro system between June 2016 and July 2017. As a result, changes in service impacted local commutes and could have affected people's decisions to drive, take transit, or use some other form of transportation to get to work.

- **Street closures and temporary parking removal:** Parades, motorcades, construction, and other activities can all prompt street closures or occupy the parking lane for an extended period. DDOT tracked street closures and developed rate recommendations for impacted blocks accordingly.

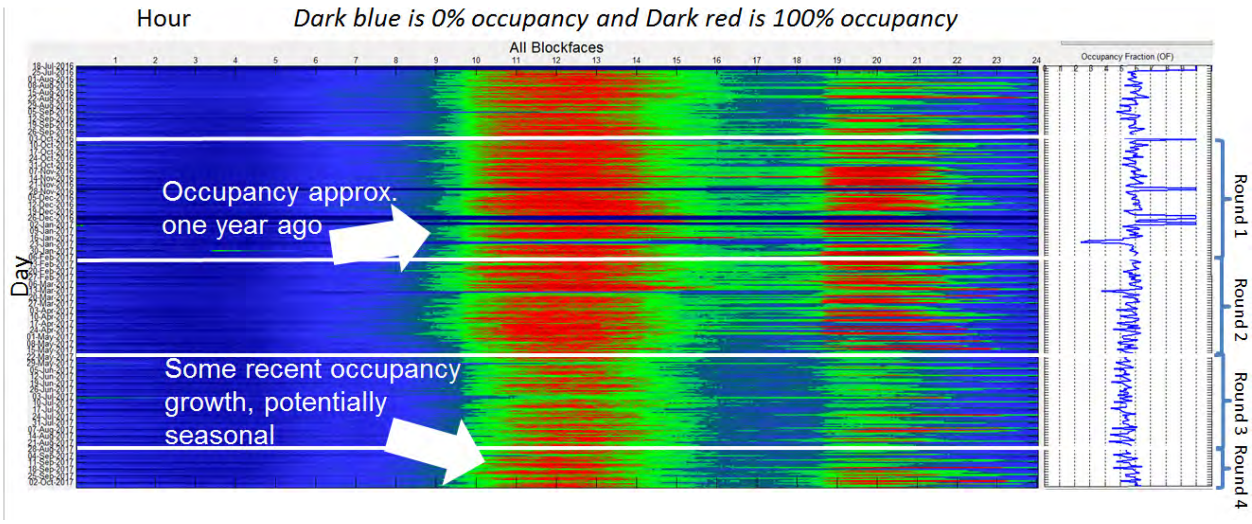
- **Capital One Arena events:** Located in the heart of the pilot area, the Capital One Arena draws thousands of visitors to the area to attend sporting and entertainment events. DDOT assessed the monthly frequency of Arena events to better determine how they may affect occupancy in the pilot area (Figure 5-22). Events generally peak between late fall and early spring, with over 20 occurring every month between October 2016 and April 2017.

Figure 5-22. Capital One Arena events by month



- **Seasonality:** Seasonal impacts also likely influenced the number of people traveling to the pilot area. Changes in activity such as holidays and Congress shifting in and out of session appear to have influenced the magnitude of visitors to the pilot area, as well as events at the Capital One Arena. Figure 5-23 uses a heat chart to show how occupancy levels in the pilot area fluctuated throughout the year.

Figure 5-23. Impacts of seasonal changes on parking occupancy



5.1.3.2 CONGESTION REDUCTION

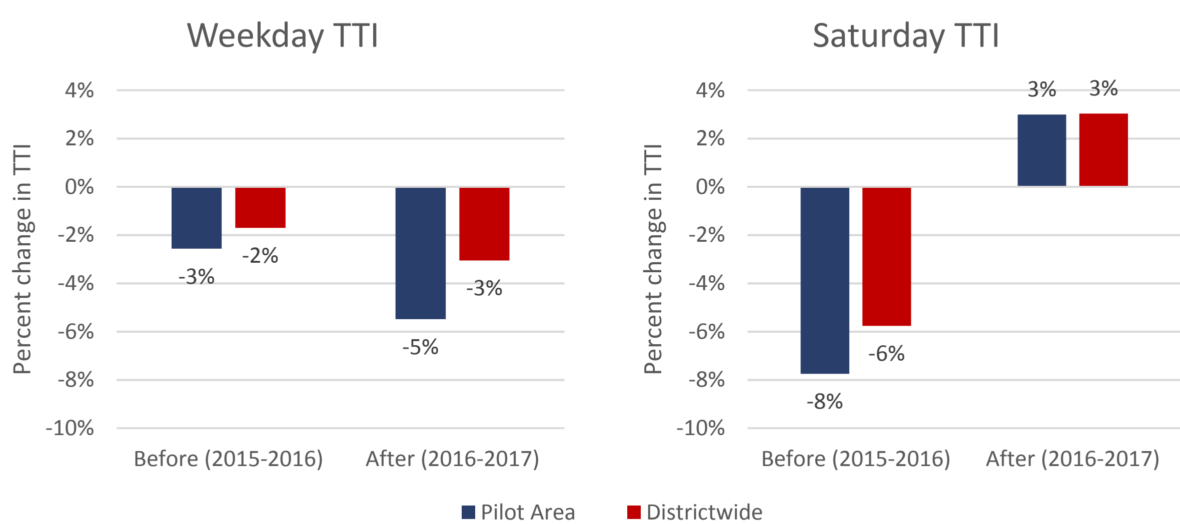
This section highlights lessons learned from the effect of demand-based pricing on traffic congestion. Major roads in the pilot area traditionally experience high levels of congestion and low travel time reliability. The parkDC pilot sought to alleviate this congestion through improved access to parking, which was expected to reduce circling for parking and double parking, both of which contribute to congestion.

Key Findings

- Congestion trended downwards during the pilot decreasing by five percent in the pilot, matching Districtwide trends which showed a three percent reduction
- Travel time reliability improved slightly during the pilot with a five percent improvement in the pilot area, matching Districtwide trends which showed a three percent improvement

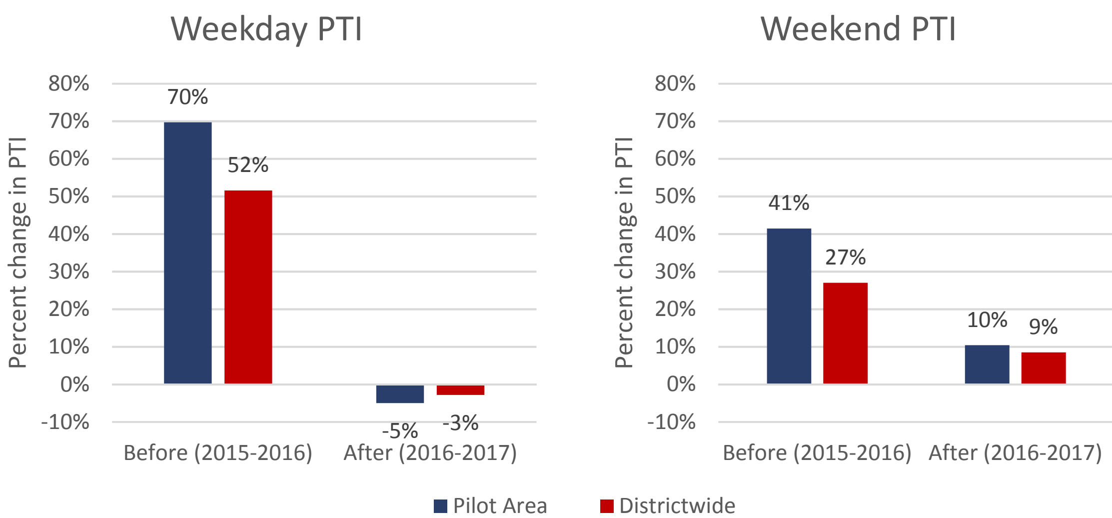
The percent change in travel time index (TTI) and planning time index (PTI) from 2015 to 2016 (before) are compared to the percent change from 2016 to 2017 (after). Congestion levels (indicated by TTI) decreased by five percent in the pilot area on weekdays, compared to a Districtwide decrease of three percent. Congestion levels increased by three percent in both the pilot area and Districtwide on Saturdays. Figure 5-24 compares percent weekday and Saturday congestion levels in the pilot area and across the District.

Figure 5-24. Average change in travel time index (congestion) scores



Travel time reliability (indicated by PTI) improved by five percent in the pilot area on weekdays, compared to a Districtwide improvement of three percent. Travel time reliability worsened by ten percent in the pilot area on Saturdays, compared to a nine percent decrease in travel time reliability Districtwide on Saturdays. Figure 5-25 compares the percent change in weekday and Saturday travel time reliability in the pilot area and across the District.

Figure 5-25. Average change in planning time index (travel time reliability) scores



The congestion and reliability data suggest that the pilot did not negatively impact traffic congestion in the area may have helped to alleviate traffic congestion.

5.1.3.3 ECONOMIC ACCESS

Parking access directly relates to people's access to school, work, entertainment, food and shopping. This section examines the relationship between the parkDC pilot and economic activity in the Penn Quarter/Chinatown neighborhoods. Economic data from within the pilot area and Districtwide showed generally positive trends after the pilot. Positive trends in sales volume, employment and the number of establishments in the parkDC pilot area aligned with trends Districtwide. As with congestion impacts, however, the parkDC pilot's impact on economic access and vitality is inconclusive.

Key Findings

- Changes in economic activity in the pilot area generally align with Districtwide trends
- Entertainment sales in the pilot area increased during the pilot despite a Districtwide decrease in entertainment sales.

DDOT assessed changes over time in sales volume, sales volume per establishment, total establishments, total employees, and employees per establishment in both the pilot area and Districtwide. Figure 5-26 shows how these economic data points changed between 2015 and 2017 in the pilot area and Districtwide.

Figure 5-26. Economic trends in the pilot area compared to Districtwide (2015 – 2017)

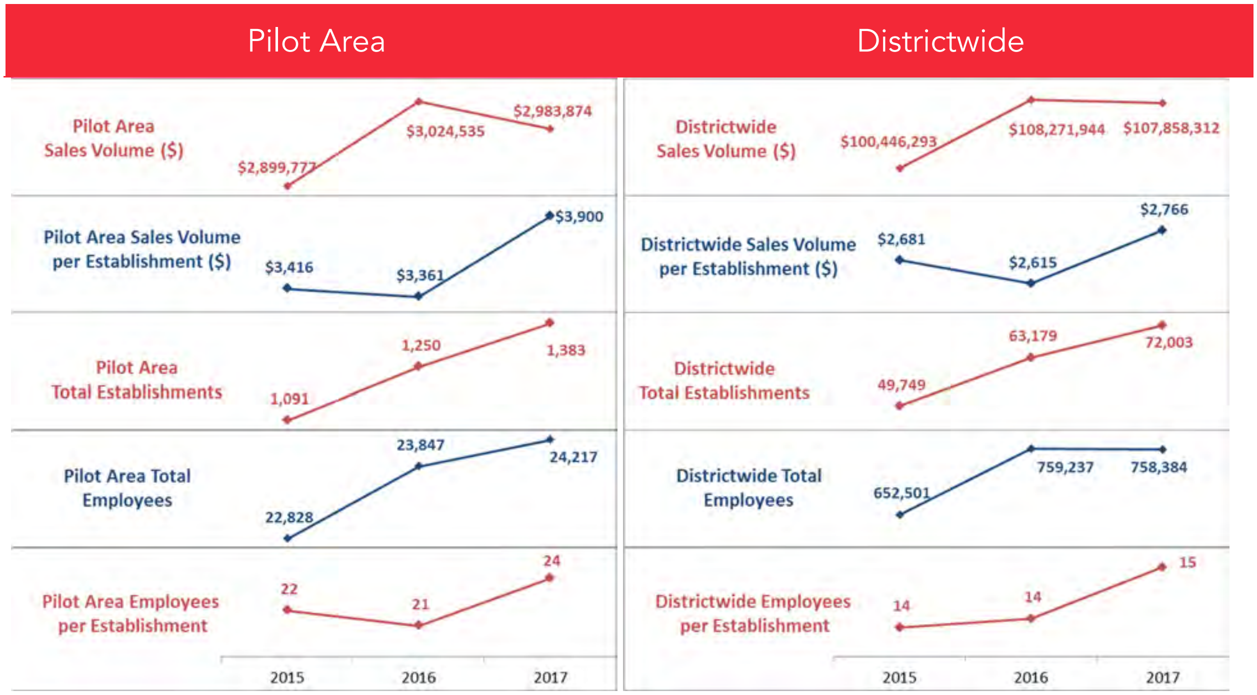
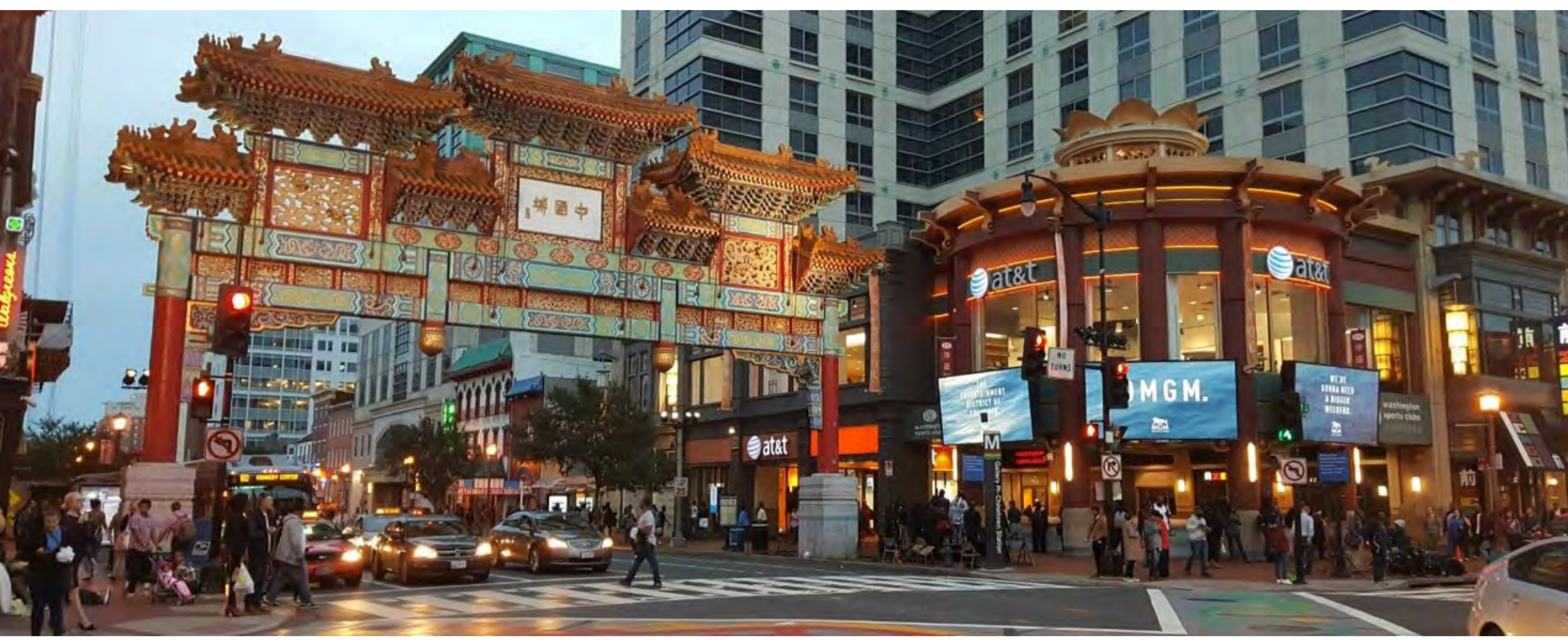


Figure 5-27 highlights how sales for specific industries changed between 2015 and 2017 in the pilot area and Districtwide. These industries provide a cross section of the economy in the pilot area and have varying demands for on-street parking throughout the day. Economic trends in the pilot area generally align with Districtwide ones, indicating that the parkDC pilot did not have a strong positive or negative effect on economic activity. The one exception is entertainment sales, which decreased Districtwide and increased in the pilot area.



Source: Wikimedia Commons, Nesnad

Figure 5-27. Sales trends for specific industries in the pilot area compared to Districtwide (2015 – 2017)

5.1.3.4 MULTIMODAL INTERACTIONS

In an urban area like the Penn Quarter and Chinatown neighborhoods, the relationships between various modes of travel make it likely that when operations for one mode changes, the other modes are affected. This section investigates potential pilot impacts on multimodal performance in the pilot area. Changes in transit, pedestrian, and bicycle activity are detailed below.

Key Findings

- Bus speeds remained relatively constant after the pilot was implemented, aligning with Districtwide trends
- Bus ridership declined slightly after implementation, aligning with Districtwide trends
- Metrorail ridership increased slightly after implementation, in contrast with a steady systemwide decline in ridership
- Capital Bikeshare ridership grew after implementation, aligning with Districtwide trends

5.1.3.4.1 Observed Changes in Bus Transit

Figure 5-28 shows average bus speeds in the pilot area and Districtwide before, during, and after the parkDC pilot. Average bus speeds in the pilot area experienced a very slight decline after the pilot (0.02 mph), but this decline matches a trend that began before the pilot (0.03 mph decline between 2015 and 2016). Districtwide, average bus speeds are higher than in the pilot area, since the pilot area is located within one of the denser, congested neighborhoods in the District. Average bus speeds outside of the pilot area similarly stayed relatively consistent before and after the pilot was implemented.

Figure 5-28. Change over time in weekday bus speeds (2015 -2017)

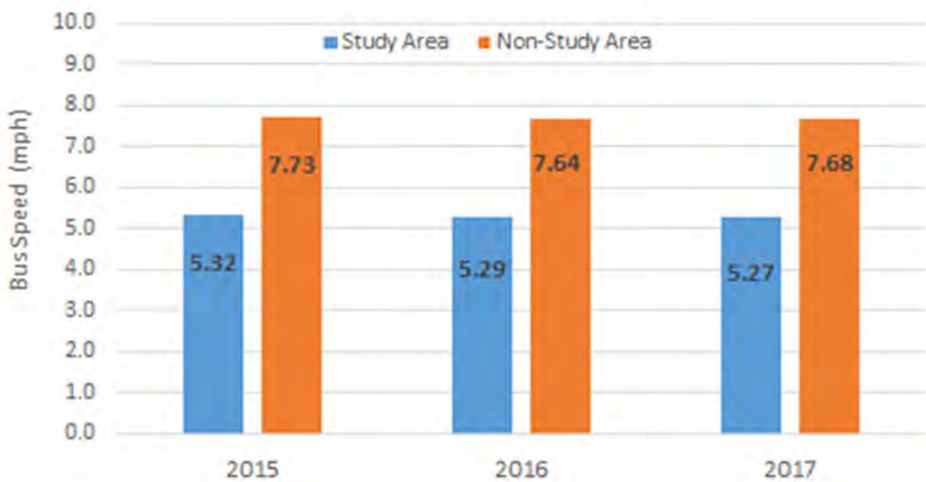
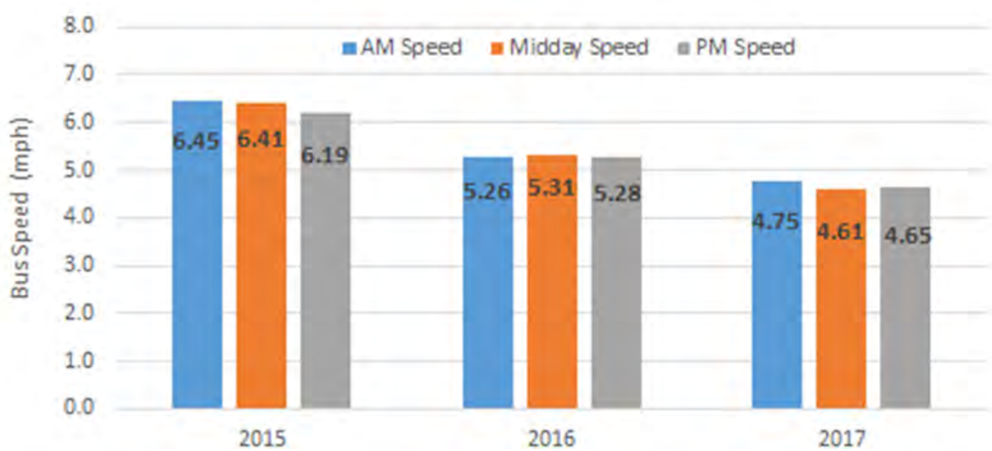


Figure 5-29 shows how bus speeds in the pilot area have changed based on time of day. The average trend of declining bus speeds occurs across all time periods. After the pilot was implemented, the greatest decreases in bus speeds in the pilot area occurred in the midday and PM peak periods.

Figure 5-29. Change in bus speeds by time of day in the parkDC pilot area



DDOT also investigated changes in bus ridership. Figure 5-30 shows changes in bus ridership in the pilot area and Districtwide before, during, and after the pilot was implemented. Average ridership in the pilot area experienced a slight decline after the pilot, but this decline matches a trend that began before the pilot. Average ridership outside of the pilot area decreased before the pilot was implemented and stabilized after implementation.

Figure 5-31 shows the percent change in daily average stop-level ridership over the course of the parkDC pilot. A range of factors are contributing to declining bus ridership in the District as a whole, including broader shifts in travel behavior and ongoing work on the Metrorail system (see discussion in next section). Ridership changes may have had a greater impact on ridership in the pilot area since average daily stop-level ridership in the area is much higher than average daily stop-level ridership Districtwide (Figure 5-31). The impacts of the parkDC pilot on bus speeds and bus ridership are inconclusive.

Figure 5-30. Change in daily average ridership by time of day Districtwide (left) and in the parkDC Pilot Area (right)

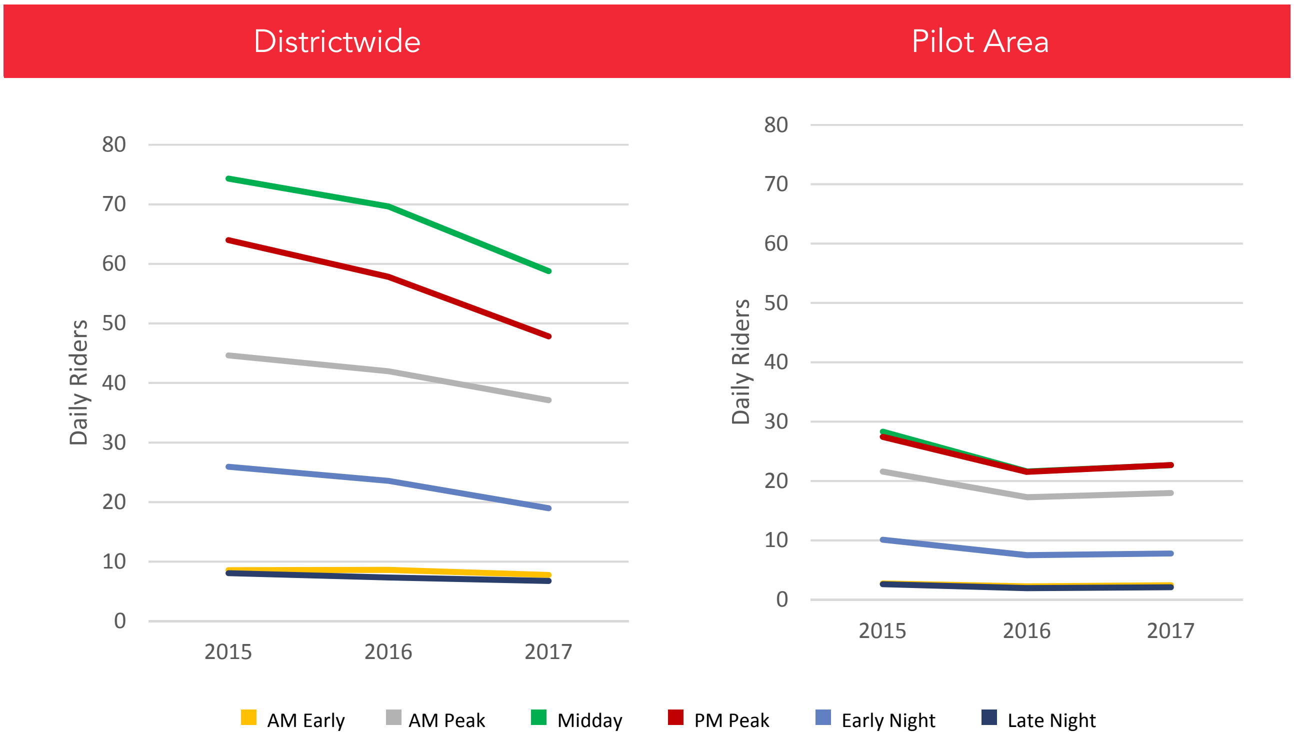
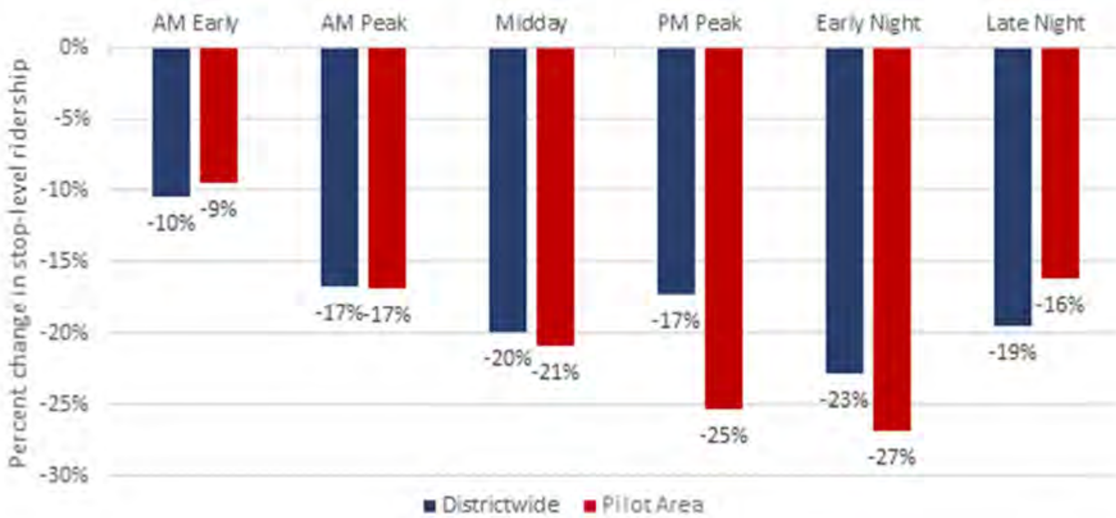


Figure 5-31. Percent change in daily average stop-level ridership (2015-2017)



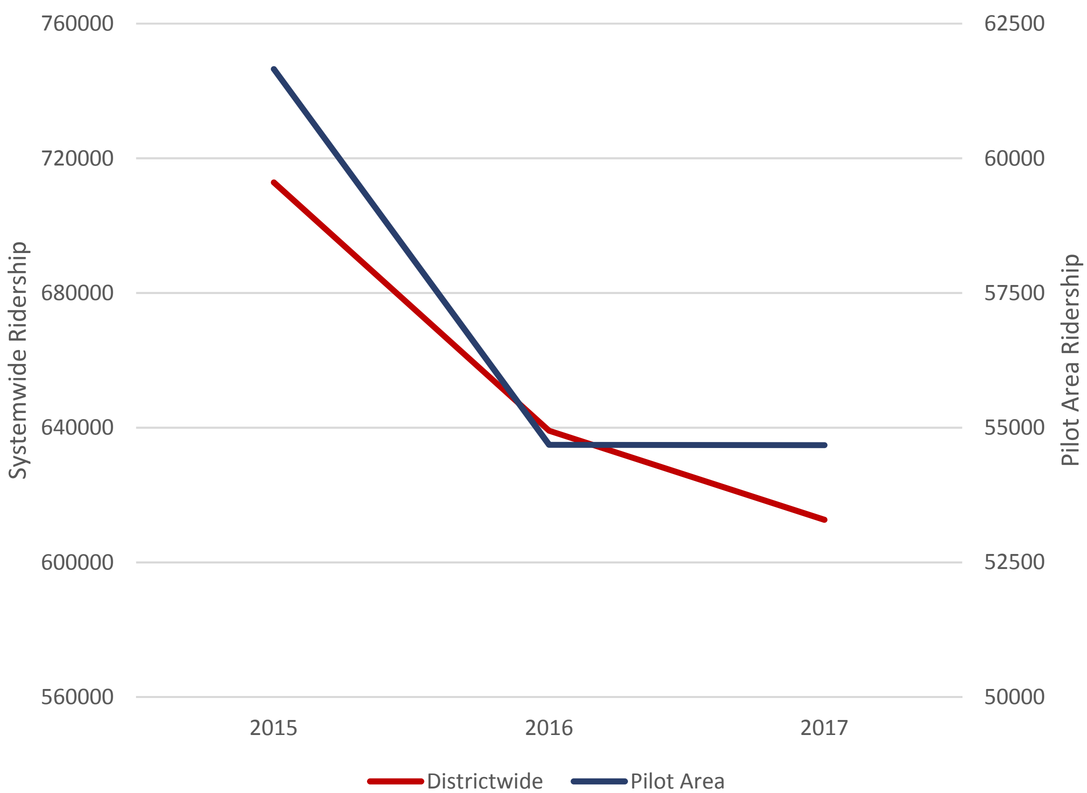
5.1.3.4.2 Observed Changes in Heavy Rail Transit

In June of 2016 WMATA announced its SafeTrack initiative, which accelerated track work on the Metrorail system to address safety recommendations and rehabilitate the infrastructure. SafeTrack included a series of "Safety Surges" that shut down line segments or necessitated continuous single-tracking for extended periods of time. These surges ranged from seven to 42 days in length, included work on each of the rail lines, and impacted stations in all three jurisdictions (the District, Maryland, and Virginia) served by Metrorail. The Safety Surges reduced capacity on the Metrorail system. To address the expected added roadway congestion during these surges, DDOT expanded hours of operation for rush-hour restricted parking. This necessitated adjusting signage and data collection to accommodate the changes.

Given the extensive work and subsequent impacts to service, the effects of SafeTrack should be considered when examining the relationship between transit performance and parking availability in the pilot area. Many changes observed in transit use may be partially attributed to SafeTrack and the pilot period being implemented simultaneously.

Data from 2015 to 2017 demonstrate the ridership for Metrorail stations in the pilot area performed better than the system as a whole (Figure 5-32). While ridership has decreased consistently for the Metrorail system, the decline in ridership at stations in the pilot area stabilized after the pilot was implemented.

Figure 5-32. Change over time in Metrorail ridership (2015-2017)



DDOT then looked more closely at the Metrorail data to see if SafeTrack had an impact on ridership in the pilot area, and if any correlation between SafeTrack and changes in parking occupancy could be identified. Figure 5-33 displays the daily entries and exits at Metro stations within the pilot area since the time of the initial price change. As can be seen, the number of entries and exits has remained relatively stable since the first price change, apart from the large increase in January 2017 which corresponds with the 2017 Women's March on Washington (January 21, 2017) the day after the Presidential Inauguration (many of the pilot area Metro stations were closed for portions of the day during the Inauguration, lowering their ridership totals). When looking at this data aggregated by month on weekdays with outliers (Inauguration, holidays, etc.) removed, as shown in Figure 5-34, it becomes evident that Metro use within the pilot area has increased since the implementation of the first price change. This compares to a ridership decrease of about 12% on the Metrorail system as a whole in a similar time period, which is largely attributed to SafeTrack.

Figure 5-33. Entries and exits per day at pilot area Metro stations

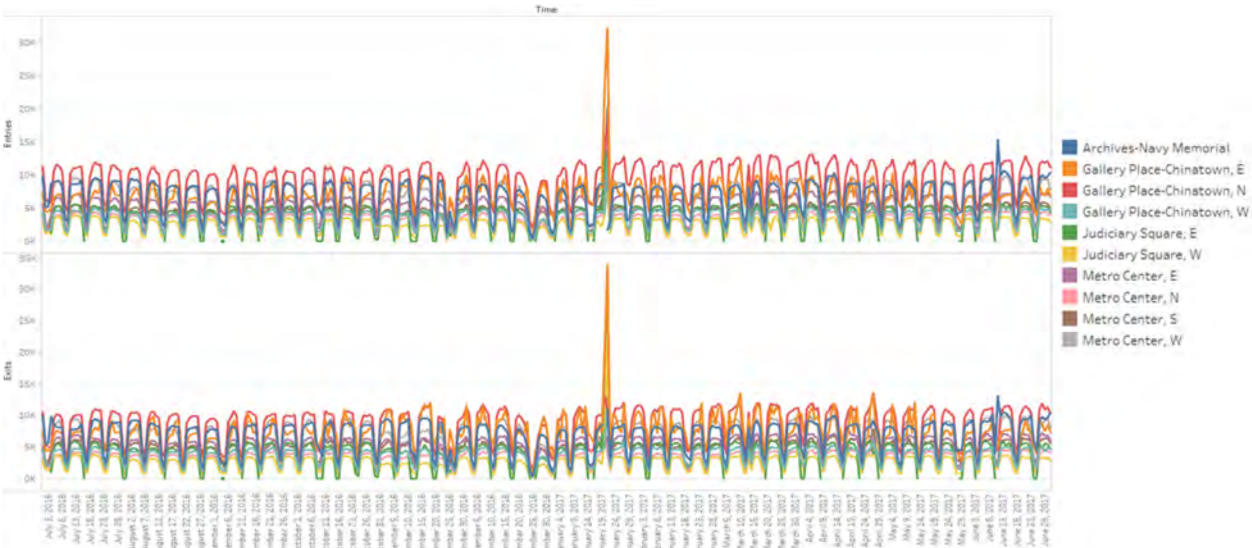


Figure 5-34. Average weekday Metro entries and exits by month (no outliers) at pilot area Metro stations

Based on the observed changes in Metrorail ridership and Metrobus speeds, the pilot did not adversely impact transit operations in the area.

5.1.3.4.3 Relationship between Parking Availability and Bikeshare

During the pilot period, arrivals at Penn Quarter/Chinatown Capital Bikeshare stations slightly outnumbered departures each year (Figure 5-35). Bikeshare ridership stayed relatively consistent before the pilot was implemented but increased by approximately 36% after the pilot was implemented.

Figure 5-35. Change over time in Capital Bikeshare ridership in the pilot area (2015 – 2017)

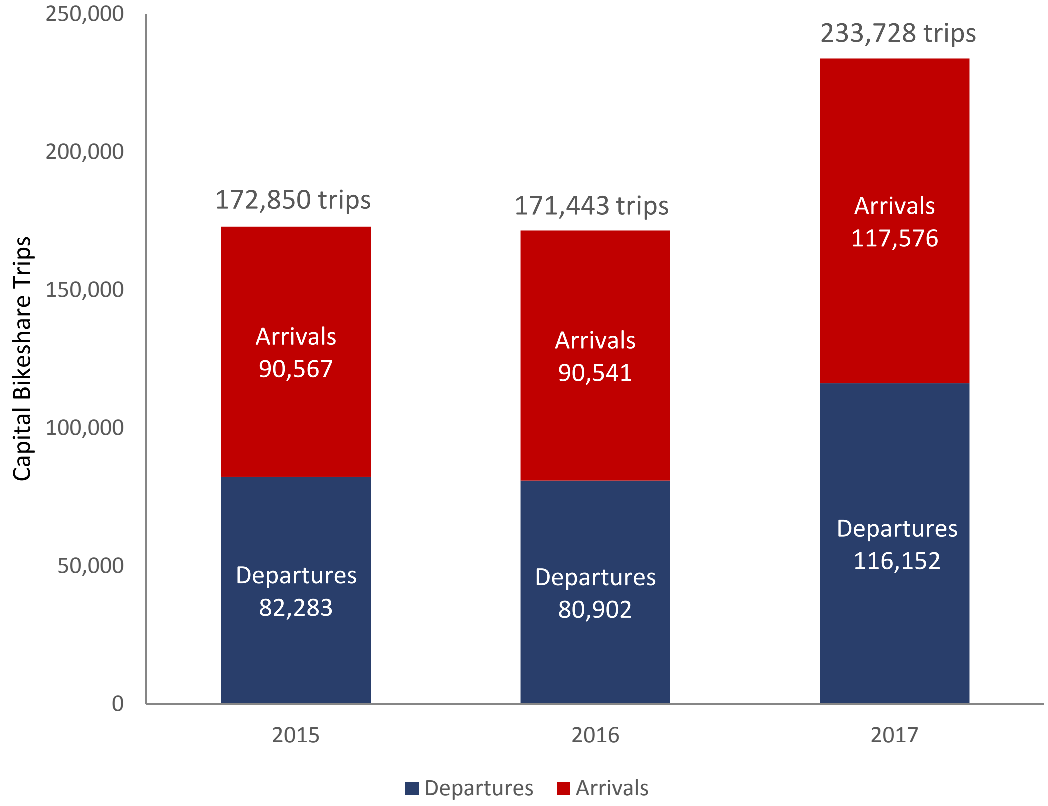
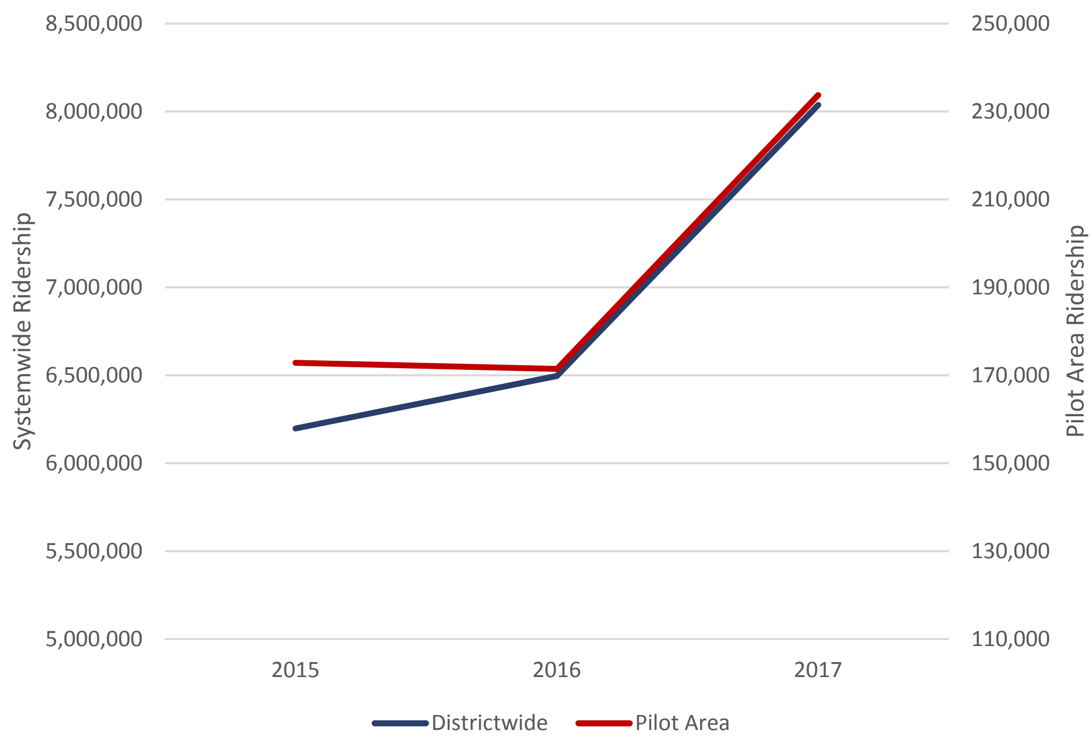


Figure 5-36 shows that the increase in Capital Bikeshare ridership in the pilot area aligns with systemwide trends. Based on the observed patterns in Capital Bikeshare ridership, the pilot did not adversely impact bicycle activity in the pilot area. As the pilot was wrapping up, dockless bike and scooter share services began operating in the District. As of the time this report was written, these new modes were currently being evaluated by DDOT, but were not evaluated as part of this effort.

Figure 5-36. Change over time in Capital Bikeshare ridership in the pilot area (2015 – 2017)



5.2 THE AGENCY PERSPECTIVE

This section provides the outcomes experienced by DDOT, the managing agency of the parkDC Penn Quarter/Chinatown pilot.

5.2.1 Managing assets effectively

DDOT's step-down approach to a data-driven demand-based pricing program proved technically viable and cost effective. By reducing the need for in-ground sensor coverage through a blend of data sources, DDOT successfully provided real-time payment information and informed their pricing algorithm at a reasonable cost.

The pilot area's location in an active downtown area presented DDOT with a range of challenges when collecting data and provided valuable lessons learned. Collecting historic occupancy data through portable CCTV cameras proved cumbersome, and sensor installation met with challenges associated with dynamic urban environments (e.g. roadway construction, changes in bus stop locations, etc.). As with any use of emerging technologies, DDOT recognized the importance of taking a "sandbox approach" to its pricing program, which would allow DDOT to test a range of technologies to find the best fit from a technical and contractual perspective. DDOT built the necessary flexibility into its program design and contracting mechanisms to test and learn how to effectively apply a mix of new technologies. This approach helped DDOT ensure that its data-driven program was not only technically effective but also cost-effective.

The conversion to pay-by-space ensured the presence of a constant number of parking spaces and allowed for the collection of real-time payment data at a space level. The enforcement of pay-by-space proved challenging for the District's enforcement staff, likely because the rest of the District maintained its usual pay-and-display parking configuration. If DDOT chooses to transition its full on-street parking supply to a pay-by-space or similar configuration, the system-wide transition will likely reduce enforcement challenges.

5.2.2 Accommodating competing users

As detailed in lessons learned from the customer perspective, results from the pilot suggest that the parkDC team was able to better accommodate competing users. Bikeshare usage increased, Metrorail ridership stabilized, bus ridership declined slightly, and motorized vehicle congestion and travel time reliability remained stable compared to pre-pilot conditions. Double parking also decreased alongside on-street parking spaces and loading zones for commercial vehicles.

5.2.3 Improving the customer experience

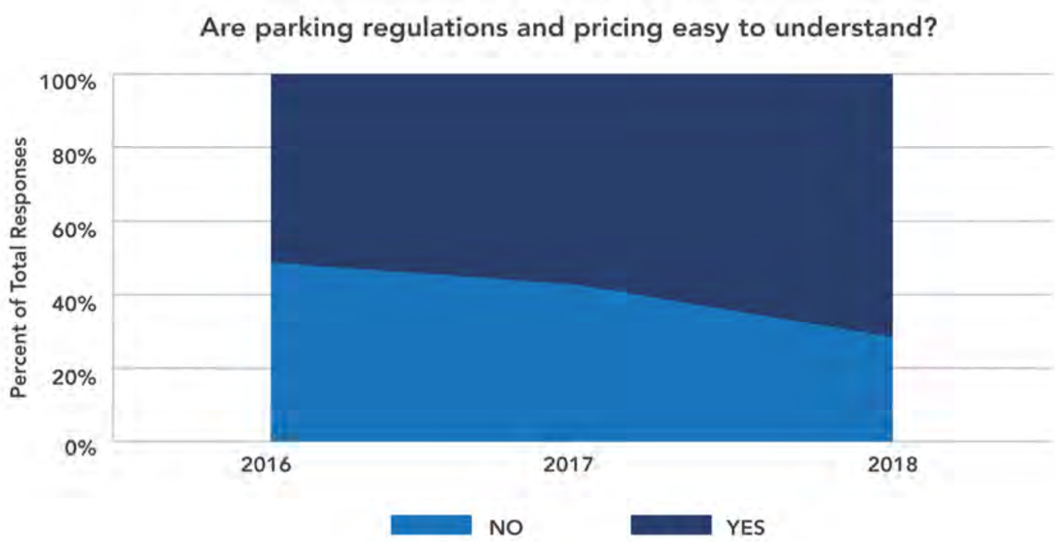
In addition to increasing available parking spaces through demand-based pricing, the parkDC pilot team made it easier to pay by improving how parking regulations and prices are communicated.

Key Findings

- Real-time traveler information apps and new parking signage improved the overall customer experience regarding parking payments.
- An ongoing customer survey showed a 15% increase in customers who think that parking regulations and pricing are clear and easy to understand.

DDOT conducted a before and after survey to begin to understand how the parkDC pilot had affected stakeholder parking experiences. While the results of the survey were not statistically significant with 196 respondents, they indicate that the various communications measures made it easier for stakeholders to understand parking regulations and pricing in the pilot area. Before the first price change, the number of people who found regulations and pricing easy to understand was split evenly with the number of people who found regulations and pricing difficult to understand. Since the first price change was implemented in 2016, the number of people who have found regulations and pricing easy to understand has increased by almost 10% while the number of people who have found regulations difficult to understand has decreased by the same amount (Figure 5-37).

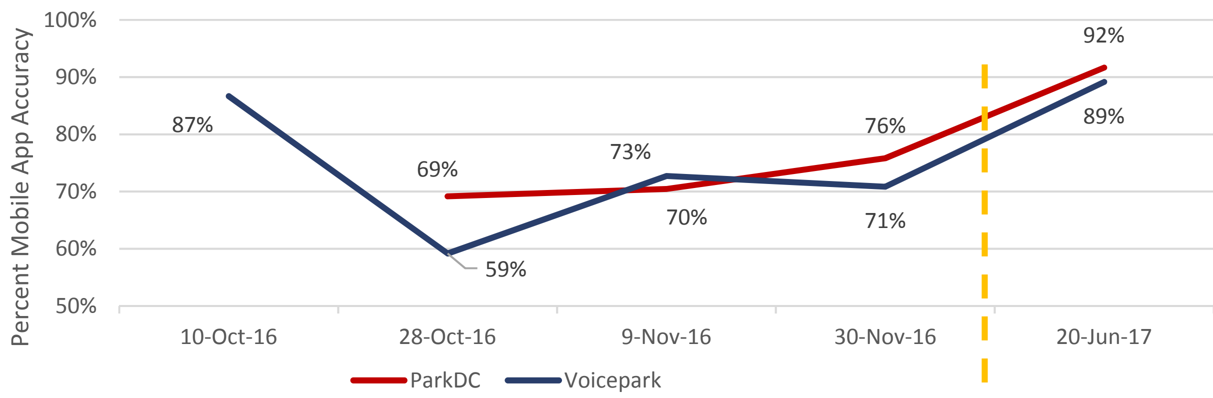
Figure 5-37. Stakeholder feedback on the clarity of parking regulations and pricing



5.2.4 Accuracy of Real-Time Traveler Information

DDOT conducted comprehensive, iterative tests of mobile app accuracy before and after both mobile applications were launched in December 2016. Figure 5-38 shows that the accuracy of both apps increased up until the launch and continued to increase, reporting between 89% and 92% accuracy six months after the launch. The positive results of the accuracy tests indicate that the iterative asset-lite approach allows DDOT to consistently improve the accuracy of real-time parking predictions. Improvement in the accuracy was due to app programming changes as well as tweaks to the real-time parking predictions over time.

Figure 5-38. Change over time in mobile app accuracy



5.2.5 Revenue stability

Key Findings

- The number of transactions remained relatively stable throughout the duration of the pilot, with seasonal fluctuations likely having a greater impact than price changes
- After an initial decrease in weekly average revenue following the implementation of the first price change, weekly average revenue collected in the pilot area surpassed pre-pilot revenue following the third price change with an increase of 10.8%.
- Due to the price changes, the amount of revenue per transaction increased during each subsequent price change

As shown in Table 5-6, the total number of transactions stayed relatively similar overall, though with fluctuations up and down over time. Seasonal factors likely had a greater impact on the number of transactions than did the price changes. After an initial decrease in weekly average revenue following the implementation of the first price change, weekly average revenue collected in the pilot area surpassed pre-pilot revenue following the third price change with an increase of 10.8% (10.8% increase in revenues from pay-by-cell and an 11.1% increase in revenues from meters). Due to the price changes, the amount of revenue per transaction increased during each subsequent price change as well.

Table 5-6. parkDC weekly revenue and transactions during the pre-pilot and after each price change

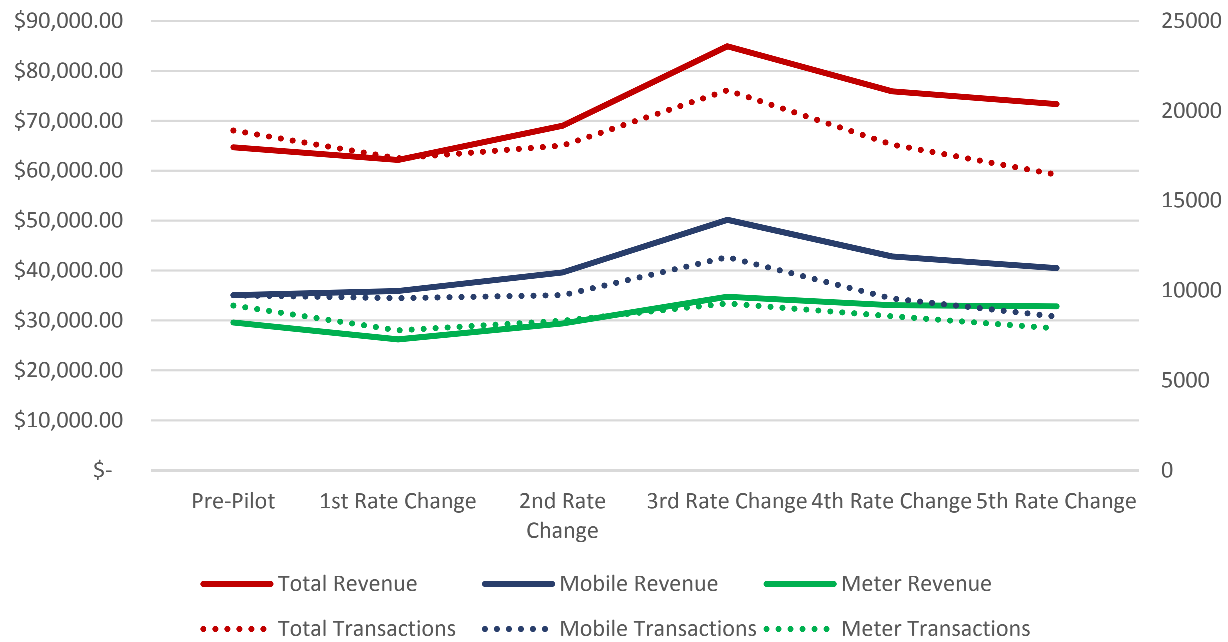
	Pre-Pilot	1st Rate Change	2nd Rate Change	3rd Rate Change	4th Rate Change	5th Rate Change
All – Transactions	*18,900*	*17,352*	*18,060*	*21,137*	*18,118*	*16,443*
Mobile Transactions	9,735	9,569	9,741	11,854	9,552	8,548
Meter Transactions	9,165	7,783	8,319	9,283	8,566	7,895
All – Revenue	*$64,656*	*$62,133*	*$69,008*	*$84,900*	*$75,871*	*$73,329*
Mobile Revenue	$35,063	$35,916	$39,617	$50,154	$42,829	$40,494
Meter Revenue	$29,593	$26,217	$29,392	$34,746	$33,041	$32,835
Revenue per transaction	$3.42	$3.58	$3.82	$4.02	$4.19	$4.46

The demand-based pricing pilot affected meter revenue by:

Implementing pay-by-space	Changing meter time limits in some locations	Adjusting rates based on demand

With the use of networked meters and mobile payments for collecting revenue, customers had several options for paying for parking. When considering the revenue by source, as shown in Figure 5-39, the weekly parking revenue increased by 17% from all sources, which includes a 22% increase from mobile payments and a 12% increase from meter payments.

Figure 5-39. Weekly parking revenue and transactions by source



Source: Wikimedia Commons, Ben Schumin

5.2.6 Cost Effectiveness

The District conducted a high-level cost-effectiveness evaluation to compare the asset-lite model to a "full-coverage" model with an in-ground sensor in every parking space. Since the objectives of the pilot—managing demand, increasing turnover, improving curbside use, promoting safety, etc.—are difficult to monetize, the cost-effectiveness model provides insights beyond typical cost-benefit analyses. DDOT's methodology involved the following steps:

1	**Identify** alternatives and determine the outcomes for comparison (e.g., accuracy, coverage, cost-effectiveness, etc.)
2	**Pilot** alternatives and measure outcomes (in this case, the full coverage and asset-lite models)
3	**Calculate** the costs of various alternatives
4	**Determine** the costs associated with the objectives/outcomes

By combining data on cost and efficacy, DDOT sought to inform future decisions in light of finite budgets. Specifically, DDOT identified several key findings to further reduce costs while maintaining the requisite level of accuracy:

- Sensor installation for the parkDC pilot cost 50% of the price of a full coverage model. This can likely be reduced further to between 35% and 40% of the cost of the full-coverage model based on additional refinement related to occupancy distribution, sensor deployment algorithms, and spatial dependence. Table 5-7 summarizes the differences in sensor cost between the two models.

- Costs for data gateway (equipment transmitting data to the back office) are represented as being half of those in a full coverage model. However, DDOT was able to reduce the number of data gateways further (approximately 15%) by applying apportionment algorithms to optimize their placement in the pilot area.

- Communication and related energy costs are based on cellular connectivity and solar power. Those costs would likely increase if landlines and AC power connections were required and additional wiring run through poles.

Maintenance is generally included in the sensor costs, but there are potential additional agency costs associated with permitting and oversight.

Table 5-7. Sensor cost comparison

	Full Coverage	Asset-Lite Model
Capital Costs*		
Sensors	$$$$	$$
Gateways	$$	$
Operations		
Communications (annual)	$$	$
Maintenance	$$	$
Baseline Data	$	$
Data Fusion/Analytics	$	$$
***Assumes 10 spaces per block, total of 100 spaces**		

One common challenge with cost-effectiveness studies is reporting, or, rather, the lack thereof. Missing data or mistaken assumptions can color the pilot results. DDOT has worked to provide a complete report the actions taken, reasons for those actions, and the results (which are available in this document and the associated data book). The goal is to ensure the models identified in this report can be translated into practice across the industry.

5.2.6.1 COST ANALYSIS

The expenses to operate a parking management program like the parkDC pilot generally include capital costs, ongoing administrative and operating costs, and enforcement costs. Within the District, DDOT is responsible for the planning and implementation costs, and ongoing administrative and operation. DPW is responsible for enforcement costs. More specifically, costs to be evaluated should include:

Capital Costs	Ongoing Support and Maintenance Costs	Enforcement Costs
▪ Per unit costs, including manufacturing, shipping, warranties, adhesive, coring, and labor for sensor installation. Also includes evaluating delays that may be caused by extremes in temperature, events, etc., and the rate of installation ▪ Gateway and communication infrastructure costs, including bucket trucks, permissions/leasing of non-municipal assets, inspection costs for said infrastructure ▪ Revenue impact of curbside closures for sensor or gateway installation ▪ Analysis to determine the optimized locations for the installation of infrastructure	▪ Monthly communications and interface costs ▪ Analysis and data visualization costs ▪ Maintenance or replacement of infrastructure as needed, due to sensor or gateway failures, permitted closures or removals, non-authorized closures or removals, and assets damaged by third parties	▪ Staff costs ▪ Device and platform costs ▪ Communication costs

From the outset and throughout the course of the project, DDOT expected a neutral direct revenue outlook based on the experiences from other cities that had previously implemented performance parking. Direct revenue is defined as revenue resulting from parking meter and citation revenue. Indirect revenues, like increases in transit use, improved sales tax receipts due to increased turnover, permit fees, etc., were not factored in projections. Managing demand properly means reducing rates in underused spaces and increasing rates where demand is highest. Consequently, shifting motorists to cheaper parking should theoretically offset revenue increases in areas where rates are higher and demand is inelastic.

Source: Bruce Emmerling, pixabay

For parkDC, however, there was an increase in direct meter revenue of approximately $10,000/week over the course of the pilot. This well surpassed the monthly operational costs and could have subsidized the initial capital costs. As discussed above, strict cost-benefit modeling fails to recognize the goals of the program that are difficult to monetize. For instance, if parking demand management programs result in travel behavior changes that address broader policy objectives, such as VMT reduction (and correspondingly, traffic congestion or air pollution), the benefits will enhance the cost effectiveness of the program. Still, setting those critical goals aside paints a positive revenue picture for parkDC. Assuming an initial capital expenditure of $800,000 in parkDC, it would take approximately 37 months for the program to break even financially. There is some evidence to suggest too that increasing rates in high demand areas will increase pay-by-cell payments, reducing wear and tear on parking meters and the need for collections. These operational efficiencies should further improve a cost-benefit analysis.

This said, the impact of similar programs in other municipalities or even other parts of the District should differ for several reasons. Some factors, among many, that will influence the cost-effectiveness and cost-benefit models include:

- Current enforcement staffing levels, citation capture rates, and meter compliance
- Present rate distribution; neighborhoods where rates are generally too high may witness revenue degradation while those where rates are exceedingly low will see revenue increases
- Hours of operation and time limits of the metered parking system influence demand, as does land use and the nature of businesses in an area
- Availability of infrastructure for communications and power will influence costs; in many cities, light poles are the property of utility companies and may require additional permissions and leases

Analysis of the parkDC project will continue and outcomes will be shared. The program provides a framework for further cost-effectiveness and cost-benefit analysis as nascent technologies are introduced and tested, occupancy proxies identified, and algorithms further improved.

Source: S Pakhrin

CHAPTER 6

Lessons Learned & Next Steps

Proving a cost-effective, data driven parking pricing program

6 Lessons Learned and Next Steps

The parkDC pilot aimed to learn whether a demand-based parking pricing program could be implemented in a cost-effective, data-driven manner. This section summarizes findings, and next steps for the District Department of Transportation.

6.1 FINDINGS

DDOT's pilot met the goals developed to meet the multifaceted challenges associated with on-street parking in the District:

Table 6-1. How the pilot met its goals and objectives

Objective	Objective Met (Yes or No)	Description
Goal: Reduce time to find an available parking space		
▪ Increase parking availability	Yes	▪ Block faces where demand matched supply increased by 16%
▪ Provide parking availability information to customers in real time	Yes	▪ Two mobile apps providing accurate real-time availability and pricing information
▪ Improve parking regulatory signage	Yes	▪ The number of customers who found signs easy to understand increased by 15%
Goal: Reduce congestion and pollution, improve safety, and encourage use of other modes		
▪ Reduce double parking	Yes	▪ The pilot area saw a greater decrease in double-parking behavior than in a nearby control area
▪ Reduce circling for parking	Yes	▪ The time vehicles spend circling for parking decreased by between 7% and 15%, depending on the time of day
▪ Encourage travel by other modes	Yes	▪ Multimodal activity remained constant or improved after the pilot was implemented
▪ Improve operations of commercial loading zones	Yes	▪ The number of minutes vehicles were observed double-parking in loading zones decreased 43%
Goal: Develop parking management solutions through a cost-effective asset-lite approach		
▪ Test different parking occupancy detection solutions	Yes	▪ A partial deployment of sensors was tested along with portable CCTV cameras, fixed cameras and time-lapse cameras to provide additional data inputs
▪ Explore effectiveness of fusing data from various sources to provide real-time availability information and inform pricing algorithms with fewer deployed assets	Yes	▪ The data sources were successfully combined to produce real-time availability information and inform pricing algorithms.

The previous chapter (Chapter 5) presents detailed pilot outcomes and emphasizes that the parkDC pilot team successfully developed a cost-effective, data-driven program. The pilot addressed parking problems for customers and the agency through strategically applied data and a thoughtfully structured program. The pilot's success indicates that demand-based parking pricing programs can be applied effectively and sustainably, particularly in crowded urban environments. The following subsections present high-level lessons learned from both the customer and agency perspectives.

6.1.1 Findings—The Customer Perspective

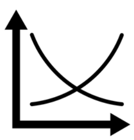
Pilot outcomes specific to the customer perspective can be divided into three levels:

- Direct curbside effects
- Pilot area network effects
- Broader transportation and land-use trends

6.1.1.1 DIRECT CURBSIDE EFFECTS

Direct curbside effects include the pilot's influence on the customer ability to find parking, customer ability to pay for parking, and instances of illegal parking. Lessons learned related to the curbside include:

Table 6-2. Direct Curbside Effects

Metric	Finding
 Supply and Demand	The parkDC pilot increased parking availability on high-demand blocks and encouraged use of underutilized parking spaces. The number of block faces with the desired level of usage (demand matched supply) increased by 16% over the course of the pilot. Customers spent less time at high-occupancy block faces and more time at low-occupancy block faces. In addition to using pricing as an incentive, DDOT increased parking time limits at low-occupancy blocks. These blocks experienced a 12% increase in occupancy and a 14 minute increase in length of stay during weekday evenings.
 Finding Parking	The parkDC pilot pricing strategies influenced demand and parking behavior. Parking availability on high demand blocks increased, along with the use of underutilized parking spaces. Various data points on parking search time point to the positive impacts of price changes on the customer experience. The amount of time vehicles spent searching for parking was reduced by two to three minutes per trip. An ongoing customer survey shows that the perceived time to find parking in the pilot area decreased by seven minutes after the pilot was implemented, though customers tend to exaggerate the amount of time it takes to find parking
 Double Parking	Double parking is a strong symptom of high parking demand and low parking supply. The pilot area saw a 55% decrease in the number of citations issued for double parking, and a 43% decrease in minutes vehicles were observed double-parking in loading zones. Both metrics point to the positive impacts of DDOT's demand-based pricing pilot on parking supply and demand.
 Parking Enforcement	Parking-related citations can correspond to a lack of available parking spaces. After the parkDC pilot was implemented, the total number of parking-related citations issued in the pilot area decreased by around 3,000 citations per month. While these findings lined up with expectations, no conclusions can be drawn from this data due to the inconsistent enforcement assumed to have occurred based on citation numbers and citation types issued throughout the duration of the project.

Metric	Finding
Pay-By-Space	The transition to a demarcated environment proved effective for DDOT and customers. The demarcation of parking spaces impacts perception and the efficient use of limited available parking spaces (Chapter 4). A demarcated environment guides customers to park more efficiently, so that customers are more likely to find a parking space.

6.1.1.2 PILOT AREA NETWORK EFFECTS

Pilot area network effects include the availability of parking information, placard use and abuse, and safety. Lessons learned related to the pilot area network include:

Table 6-3. Pilot Area Network Effects

Metric	Finding
Cruising for Parking	The parkDC pilot proved effective in reducing cruising rates and cruising-related vehicle miles traveled (VMT). The percent of vehicles observed cruising for parking decreased between 7% and 15% over the course of the pilot, indicating that customers were able to more quickly find available spaces.
Availability of Parking Information	DDOT's cost-effective, data-driven approach to demand-based pricing enabled the agency to increase the frequency and accessibility of parking information. Two mobile applications that provided real-time estimates of parking availability each reached an average of three-hundred users a month. New parking signs and calendar-style decals on parking meters more clearly conveyed information about when customers could park and how much parking would cost. An ongoing customer survey showed a fifteen percent increase in customers who think that parking regulations and pricing are clear and easy to understand.
Placard Use	Compared to comparable street networks in the District, placard use was higher in the pilot area before the parkDC pilot was implemented. After the parkDC pilot was implemented, placard use declined by fourteen percent in the pilot area compared to ten percent in the control area. In addition to the parkDC pilot, a Districtwide transition to dedicated Red Top meters for customers with disabled parking placards likely contributed to the decline in placard use.
Safety	Although detailed safety data were not available for analysis during the pilot implementation period, the pilot's role in making it easier to find and pay for parking likely resulted in more predictable motorist behavior and fewer erratic movements.

6.1.1.3 BROADER TRANSPORTATION AND LAND-USE TRENDS

Broader transportation and land use trends include impacts on multimodal mobility and economic vitality. Lessons related to broader transportation and land use trends include:

Table 6-4. Broader Transportation and Land-Use Trends

Metric	Finding
Congestion	Data from within and outside the pilot area had generally positive trends after the pilot. Weekday motorized vehicle congestion decreased in both the pilot area and Districtwide following the pricing pilot. Weekday motorized vehicle travel reliability improved slightly in both the pilot area and Districtwide following the pricing pilot. The pricing pilot's impact on motorized vehicle congestion and reliability is inconclusive.
Economic Access	Economic data from within the pilot area and Districtwide had generally positive trends after the pilot. Positive trends in sales volume, employment and the number of establishments in the parkDC pilot area aligned with positive trends Districtwide. Similarly to congestion impacts, the parkDC pilot's impact on economic access and vitality is inconclusive but suggests the pilot did not negatively affect local businesses.
Multimodal Activity	Multimodal data from within the pilot area had varying, largely positive trends after the parkDC pilot was implemented. Consistent with Districtwide trends, after the pilot was implemented Capital Bikeshare ridership increased, bus speeds remained relatively stable, and bus ridership declined slightly. Despite ongoing delays and disruptions related to system repair efforts, Metrorail ridership in the pilot area stabilized after the pilot was implemented. This stable trend contrasts with systemwide activity, which continued to exhibit a downward trend. Similar to congestion and economic impacts, the parkDC pilot's impact on multimodal interactions is encouraging but inconclusive.

6.1.2 Findings – The Agency Perspective

Pilot outcomes specific to the agency perspective are related to:

- Effective asset management
- Pricing
- Improving customer experience
- Revenue stability

Table 6-5. Agency Findings

Metric	Finding
Effective asset management	The District's step-down approach to a cost-effective, data-driven demand-based pricing program proved technically viable. By reducing necessary in-ground sensor coverage through a blend of data sources, DDOT successfully provided real-time payment information and informed the pricing algorithm at an affordable cost. Due to the pilot's location in a vibrant, downtown area, DDOT contended with a range of urban challenges when collecting data for its algorithm. The process for collecting historic occupancy data through CCTV cameras proved cumbersome, and the installation of sensors met with challenges inherent to the urban environment. Flexibility built into the program design and contracting mechanisms allowed DDOT to test and learn how to effectively apply a mix of new technologies, ensuring that this data-driven program was both technically effective and cost-effective.
Pricing	The parkDC pilot demonstrated that pricing can be successfully applied as a demand management tool for curbside parking in the District. In course of the five price changes, DDOT decreased rates on seven percent, increased rates on thirty-one percent, and maintained prices on sixty-three percent of all block faces. Due to the District's conservative approach to price changes, less than one percent of all block faces jumped more than two price bands during a price change. Less than one percent of all block faces decreased to the lowest rate and had to be increased during the following price change. All block faces that were increased to the highest rate were not decreased during the following price change.
Improving Customer Experience	As detailed in lessons learned from the customer perspective, the parkDC pilot helped DDOT improve the customer experience. The parkDC team actively sought to make parking rules and regulations clearer and provided real-time parking information to customers. The implementation of pay-by-space eliminated the need for customers to return to their vehicles after paying for parking. Customer surveys also indicate a positive trend in customer experience in the pilot area.
Revenue Stability	The parkDC team did not seek to increase revenue as part of the pilot, but parking revenue did increase slightly during the pilot. Total parking revenue increased by seventeen percent, mobile-based parking payment revenue increased by twenty-two percent, and meter-based parking payment revenue increased by twelve percent. In contrast to the increase in parking revenue, the number of parking transactions decreased slightly during the pilot. Total parking transactions decreased by four percent, mobile-based transactions decreased by two percent, and meter-based transactions decreased by seven percent.

6.2 URBAN CHALLENGES – LESSON LEANED

The complex urban environment, with its multiple transportation modes and greater density of buildings and people, presents unique challenges. These challenges, organized by type, are discussed in the following sections.

6.2.1.1 PARKING OCCUPANCY SENSORS

DDOT identified lessons learned from their experience with occupancy sensors that can be applied to any urban environment:

Table 6-6 Parking Occupancy Sensors

Category	Description
Installation Challenges	
Closure of On-Street Parking	Restricting parking on District streets to install items like in-ground sensors involved permitting and public notification processes. Further coordination was needed to avoid conflict with events at the Capital One Arena. Despite closures being announced in advance along with posted signs and cones on the street, drivers continued to park in the closed on-street parking spaces. This delayed the installation of the in-ground sensors and required involving enforcement officers and tow trucks. In some cases, however, the vehicles belonged to government agencies and could not be towed. In these cases, personnel were required to install sensors in off-hours or a later date when they found the space open.
Installation Conditions and Noise Restrictions	Less than ideal weather conditions also required work during off-hours, including at night, but nighttime noise restrictions allowed only small windows of time to install sensors only between busy daytime hours and overnight noise restriction hours. A prolonged stretch of rainy weather meant conditions during installation were often wet, requiring the use of heaters to dry holes and ensure the epoxy formed the necessary bond. Occasionally, work could not be completed during the week scheduled because of competing construction work or other projects, necessitating additional trips and coordination activities.
Mapping	During installation, sensors were mapped to verify that they were installed in their intended locations. The removal and addition of a few metered parking spaces during installation necessitated real-time changes to the designs and modifications to the installation plan. DDOT required an accurate sensor location map to minimize potential impacts from future construction or repaving efforts. After the sensors were installed, occupancy information was integrated into an available API to enable future release of a traveler information system and mobile applications. This was an iterative process and required several adjustments to get right, especially as it pertains to space numbering conventions.
Communication Challenges	
Jamming Devices	During testing of the installed in-ground sensors, a sensor vendor identified issues with jamming devices being used in adjacent government buildings.
Intense Mobile Signal	What was believed to be a very strong mobile signal was being emitted from the Capital One Arena, previously the Verizon Center, located within the pilot area. This affected sensor functionality.

Category	Description
Power Outages	On one occasion, 15 sensors were impacted by a fire that knocked out power to a street light pole and sensor gateway.
Bus transit and Metrorail Trains	Buses sometimes created false positives and Metrorail trains below the roadway also impacted sensor readings. The vendors had to adjust the some of the sensitivity parameters to adjust for these interferences.
Installation	Communication issues arose when a modem was found to be failing due to water damage caused by the over-tightening of a screw in the modem housing during installation. In this case, the modem failure took approximately 30 networked sensors offline until it was replaced.

Lessons Learned

Allow for flexibility	The ever-changing urban environment makes it almost impossible to expect baseline conditions to remain constant. Despite DDOT's best efforts to identify a controlled area and put in place moratoriums on construction and curbside use changes, factors outside of DDOT's control necessitated flexibility and adjustments to the pilot area. In some cases, the changes were viewed as opportunities to collect additional data and to analyze the impact they had on parking occupancy and mobility within the pilot area.
Start monitoring early	Early issues with sensor installation and communication can be identified and addressed by monitoring the pings, or "heartbeats," from installed sensors. Furthermore, working with vendors early, before installation, helps address issues related to interference, jamming signals, or communication issues. Early monitoring should also extend to on-street activities that will affect the ability to collect data.
Consider special events	All major cities have unique special events that impact demand for on-street parking in different ways. Considering how these events operate and how the parking ecosystem can be designed to accommodate them can help minimize customer complaints and improve system efficiency.
Communicate early and often	Inter- and intra-agency communication were imperative as the project moved forward. In the parkDC pilot, conversations within DDOT, and externally with other agencies and neighborhood groups (the business improvement district, neighborhood associations, and the local Advisory Neighborhood Commissions) helped educate the public, inform agencies of impending changes, and flag issues for the project team to address.
Explore policy solutions	Some challenges with customers cannot be addressed by pricing or enforcement alone. DDOT's policy changes around loading zone pricing (extant when the pilot began) and Red Top meters reserved access for certain curbside users to address larger system and user needs.
Budget for sensor relocation	Despite DDOT's best efforts to avoid disruptions to the installed sensors, inevitably sensors were impacted due to construction or roadway restriping/reconfiguration. Having budget previously allocated would have made sensor relocation easier.
Develop a transition plan for the end of the pilot	Provide budget and contracting mechanisms to be used if the pilot is successful and becomes part of typical day-to-day operations. This includes on-going budget for managing the system, operating assets, and developing new pricing structures.

6.2.1.2 LIMITED SPACE, MANY DEMANDS

6.2.1.2.1 Relocating CCTV Cameras

At the outset of the project, six trailers with cameras were moved on a weekly basis throughout the pilot area to capture baseline data. Because single cameras did not cover many spaces, multiple cameras were often needed to cover a full block face. While the trailers were intended to minimize impacts in the urban environment, they were still disruptive, each being about the size of a compact car.

Moving the trailers each week was labor intensive and could take several hours per trailer. At each location, the trailer had to be placed either on the sidewalk—potentially impacting pedestrian activity—or in a parking space, reducing revenue opportunities and potentially compromising the goals of the pilot. Further, in many locations, rush hour restrictions and construction permits restricted the ability to use camera trailers. Community members raised concerns, including a local organization that did not want an unsightly camera placed near the entrance to their downtown office building with VIPs arriving for a major meeting.

6.2.1.2.2 Demands for Pole and Traffic Cabinet Space

Space on signal and light poles at intersections is already at a premium, and as cities increase the use of sensing technologies, the problem will only worsen. For the parkDC pilot, hardware that supports in-ground sensors needed to be hung from signal and light poles at intersections in the pilot area. Additional space was needed for Bluetooth sensors at 59 intersections to measure the number of vehicles cruising for parking.

> Space on signal and light poles at intersections is already at a premium, and the problem will only worsen.

Another challenge was lack of space in traffic signal cabinets to house the variety of computing, networking, power management, data storage, and communication electronics needed by the in-ground sensors. A separate enclosure had to be created to house cellular modems and access point controllers. The new enclosures required a power supply. When solar power was not feasible, they needed to be connected to streetlight poles, which required significant coordination and discussion with the Potomac Electric Power Company (PEPCO), the public utility supplying power to the District, around who would pay for power. DDOT signal technicians needed to be on hand to oversee the electrical connections and bucket trucks brought in to install the gateways, repeaters, and other communications infrastructure.

6.2.1.2.3 Demarcation

The pilot area was converted from pay-and-display to pay-by space to improve sensor accuracy, to allow for collection of transaction data at a space level, and to improve the customer experience. Items necessary to convert from the previous pay-and-display environment to pay-by space included:

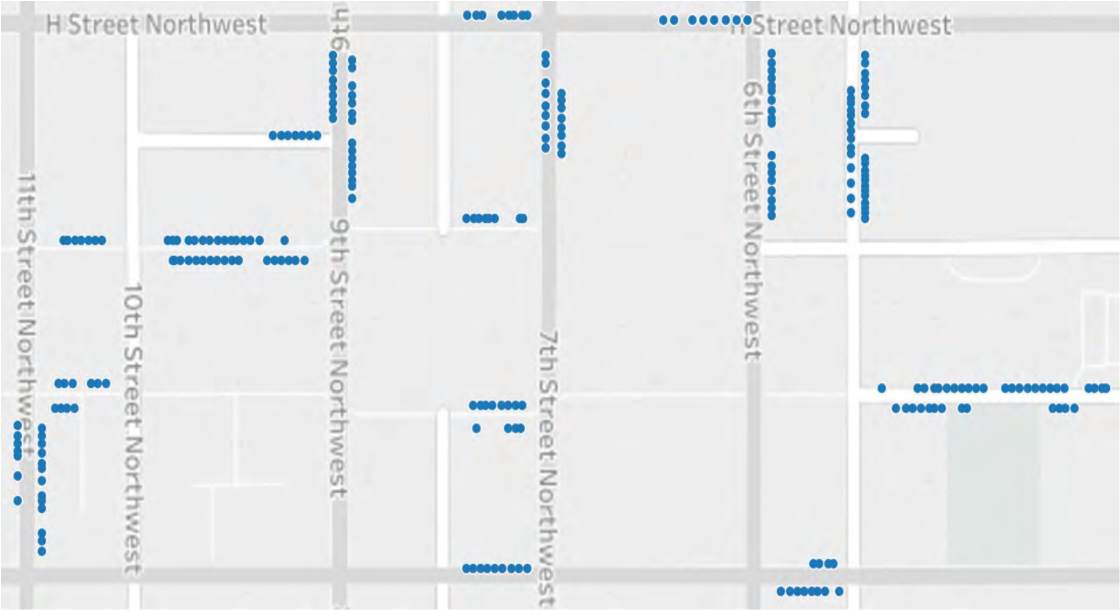
- Installing and maintaining new space marker signs (paint was not used);
- Updating meter and enforcement software;
- Incorporating language flexibility into contracting to accommodate changes to curbside space;
- Conducting public outreach to explain the change; and,
- Performing field reviews to ensure the markers and software denote the correct spaces.

6.2.1.3 ON-STREET ACTIVITY AFFECTING DATA COLLECTION

On-street activities like paving and restriping, construction, emergency utility work, or road closures may impact data collection. To prepare for these disruptions, the project team needed to know when these activities were expected to occur. DDOT has an online Transportation Online Permitting System (TOPS) that allows District residents and businesses to apply for permits and for DDOT to internally monitor the requests. At the pilot's onset, DDOT set up email alerts so the project team would automatically receive a message for any request in the pilot area. However, the abundance of requests quickly became overwhelming, and the system was modified to pass along only requests that required closure of a space in the pilot area. DDOT also relied on its stakeholder identification process and communication plan

(Chapter 4) to identify and prepare for agency-initiated disruptions not included in TOPS, such as WMATA bus stop relocations and DDOT roadway construction projects.

Figure 6-1. Block faces with construction permits and their associated on-street parking spaces during the fourth price change



A summary of these disruptions, includes:

Metric	Finding
Paving and restriping	Paving and restriping can change the roadway configuration, including removing or relocating on-street parking spaces. The project team tried to place a moratorium on changes in the pilot area, but the rapidly changing urban landscape, including building developments that were not going to be held up, still made changes necessary
Construction	Whether on the road itself or at an adjacent building, construction can require closure of on-street parking and does not allow for real-time data to be collected. The data reviewed for the fourth price change identified 26 block faces (29% of the pilot area) with construction activity, shown in Figure 6-1, and therefore no real-time occupancy data. For smaller construction projects, the project team identified the location, duration, and extent of the impact to address the data discrepancy from the affected in-ground sensors. Larger construction projects, such as the National Law Enforcement Museum, which closed the 400 block of E Street NW, also created impacts, but were easier to deal with because they provided longer notification lead times.
Steel construction plates	Steel construction plates used during in-street utility construction were periodically found to be covering the sensors, creating false positive readings. Additional coordination was needed to get the steel plates moved or to temporarily remove the data from those sensors from the algorithms.
Curbside Management	Routine curbside activities such as extended reservation of parking spaces for loading and unloading, construction, street festivals, or other activities can regularly put on-street parking spaces out of service for several hours, several days, or several weeks in some cases.

6.2.1.4 SPECIAL EVENTS

The Capital One Arena, a sports and entertainment venue at the center of the pilot area, regularly holds events that can create additional roadway congestion. DDOT took a focused look at arena events to determine their impact on parking use in the pilot area, and whether event-based pricing would have performance benefits. Based on the reviewed event data, DDOT shelved the idea of applying event pricing in the pilot area and will instead adjust rates based on historical seasonal use. This has the added benefit of being easier to communicate to the public and should not raise the percentage in the rate-adjustment calculations because the number of events at the Arena varies consistently by season.

6.2.1.5 BROADER MOBILITY AFFECTING DEMAND

The urban core of the District, including the Penn Quarter/Chinatown neighborhoods are affected by situations causing changes to the transportation system both locally and region-wide. These situations tend to reverberate regionally and have especially large and compounded impacts in the District. Within the pilot area, WMATA's SafeTrack initiative, events at the Capital One Arena, festivals, and large events like the Papal Visit, Presidential Inauguration, and Women's March on Washington all impact mobility directly within the pilot area with reverberating effects regionally.

6.2.1.6 PARKING USERS

The types of users of on-street parking spaces vary, with commuters, tourists, and retail shoppers comprising most of the population. Within these groups, special circumstances, occupations, or employers allow for the use of placards. These include disabled placards, government-vehicle placards, or those for delivery vehicles. Many of these placards allow vehicles to park in certain—or sometimes all—on-street parking spaces without paying and for longer time periods than other vehicles. Because these vehicles are insensitive to price changes, other strategies need to be employed to monitor and shift these parking users. This included outreach to law enforcement and other agencies as noted below in interagency coordination, exploring alternative pricing strategies for loading zones to discourage misuse, and implementing the Red Top Meter Program to reserve parking for disabled placard holders but require payment and impose time limits for that use.

6.2.1.7 INTERAGENCY COORDINATION

Because varying agencies develop parking regulations and policy (DDOT), enforce parking regulations (Department of Public Works, or DPW), adjudicate (Department of Motor Vehicles, or DMV) and supplement enforcement (the Metropolitan Police Department, or MPD), multiple municipal agencies needed to be at the table to move forward with tasks like changing the payment structure from pay-and-display to pay-by-space parking. When they payment structure changed, handheld devices used by enforcement officers also had to be updated, subjecting DDOT to interagency contracting challenges. In addition, officers required training on the change to demarcation. These efforts were funded by DDOT but carried out by DPW.

Due to construction and other on-street activities, WMATA occasionally moves bus stops. When this happens, coordination helps ensure demarcated parking spaces are taken offline, and sensors are removed from reporting real-time occupancy information.

The presence of federal government buildings and related security measures in Washington, DC makes it necessary to coordinate with additional agencies. The installed assets, including cameras and gateways, were marked with stickers to inform non-District personnel, especially security agencies, of their intended use. DDOT's logo and phone number were also placed on the stickers for verification.

Before the pilot began, many law enforcement vehicles parked within the eastern third of the pilot area. Users of these vehicles are exempt from paying for parking—a missed opportunity to collect revenue and payment data in the pilot area. As part of this project, DDOT reached out to MPD and the Federal Bureau of Investigation (FBI) to encourage officers from both agencies to limit on-street parking of their agencies' vehicles to blocks already designated for government vehicles.

6.3 NEXT STEPS

Based on the positive lessons learned from the parkDC pilot, DDOT recommends scaling up its cost-effective, data-driven approach to demand-based pricing to other District neighborhoods. The results of the parkDC pilot suggest that expanding demand-based pricing should have positive compounding effects. An expanded program would resolve challenges associated with communicating the pilot area boundary and different payment mechanisms (pay-by-space vs. pay and display) to customers, and communicating system operations to other District agencies (e.g. enforcement). This section details specific steps that the District can take to expand its demand-based pricing program.

6.3.1 Expand Demarcated Parking

As demonstrated in the parkDC pilot, demarcated parking offers a range of benefits such as increasing the efficiency on on-street parking utilization, providing greater clarity to customers, and supporting a cost-effective, data-driven demand-based pricing program. The parkDC team recommends using demarcated parking at all metered on-street spaces across the District, with or without a shift to pay-by-space (without pay-by-space, demarcation would only entail marking or designating individual parking spaces). Future efforts could help identify appropriate strategies, including the potential use of pavement markings, for designating individual parking spaces. The migration to demarcated parking should include a move towards a more effective enforcement strategy.

6.3.2 Deploy Incremental but Intentional Expansion Plan

Given the positive effects of the parkDC pilot, the parkDC team recommends expanding the demand-based pricing pilot to more areas of the District. The team recommends an incremental but intentional expansion neighborhood by neighborhood, starting with the existing performance pricing zones (as described in Chapter 2), then seeking to move into other areas most impacted by congestion. Neighborhood selection should be guided by data and analysis, including multimodal mobility data from DDOT's *District Mobility* project.[1] Each neighborhood should consist of a workable and sustainable number of metered on-street parking spaces, approximately consistent with the size of the parkDC pilot area.

As the parkDC program expands to other neighborhoods, DDOT should initially baseline on-street parking prices based on paid use block by block. DDOT should also implement a data-driven approach to time limit modifications while also seeking consistency in time limit and pricing time periods across the District. Any exceptions to standard time limits and pricing time periods should be established using data.

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[1] District Department of Transportation. District Mobility: Multimodal Transportation in the District. January 2017. https://districtmobility.org.

The original business rules related to pricing changes should be revisited and revised based on data and customer feedback to accurately reflect the expansion plan. Before expanding, the following should be done for each new expansion area:

- Determine the boundaries and block faces to be included in the expansion area using established business rules
- Inventory and map curbside spaces and off-street garages in the expansion area
- Identify upcoming or proposed projects with potential to impact curbside use during construction

6.3.3 Expand the Deployment of Occupancy Detection Technology

Several factors will influence the final mix of devices deployed as the parkDC pilot is expanded. Variations in street configuration and parking demand mean different devices may be more appropriate in different areas. For example, a block lined with trees may create occlusions for overhead cameras while long blocks may be better for overhead cameras if visibility allows for fewer cameras than sensors given the number of spaces.

Similarly, while sensors and permanently mounted cameras provide highly accurate data, they are both expensive and difficult to maintain. Sensors are prone to interference, have only been shown to work effectively in demarcated parking environments, and often fall victim to street work (construction and snowplows). Permanently mounted cameras can run into issues when communication lines are disconnected for street work or for events, and the cameras must be maintained to ensure optimal performance. Reducing the number of sensors and cameras reduces exposure in addition to saving money.

From the current deployment and through additional testing DDOT expects to identify the most promising and cost-effective technologies for measuring various types of parking behavior, including occupancy, turnover, frequency of use, and vehicle type information. Currently, several technologies show promise in their ability to collect one or more type of parking behavior.

6.3.4 Continue Test of Alternative Technologies

A key benefit of the parkDC pilot was its ability to test and apply state of the practice occupancy detection technologies to better balance the supply and demand of on-street parking. The long-term success of a Districtwide program will depend on the thoughtful testing and application of emerging and alternative technologies. Technologies such as automatic license plate readers, dome mounted-sensors, and crowd-sourcing applications can serve as an alternative to more expensive in-ground sensor technologies and can provide additional benefits such as data-based suggested routing capabilities for customers. While the parkDC pilot did not comprehensively test these technologies, DDOT did begin to investigate their potential benefits and challenges:

- Use of **license-plate recognition** (LPR), also known as automated license plate recognition (ALPR) is becoming more common. While LPR systems are most commonly used for enforcement (including the use of LPR for enforcement of residential parking in the District), other on-street detection uses could include parking occupancy, parking duration/turnover, and parking frequency. LPR systems can be fixed, installed on portable platforms, installed on vehicles, or installed on handheld platforms. Often, opportunities exist to place LPR systems on fleet vehicles (e.g., police vehicles, trash collection vehicles, or transit vehicles) already on city streets. LPR/ALPR poses some challenges, including irregular or infrequent data collection, long term storage for data captured, GPS inaccuracies and the need for accurate curbside inventories, and perceived privacy issues from the public.

- **Dome-mounted sensors** or sensors mounted directly within the dome of a single-space parking meter show promise because they are non-intrusive to install and easy to access for maintenance and/or replacement. Because the dome-mounted sensor is attached to the networked single-space meter, no additional communication equipment is needed to transmit data. This solution only works where single-space meters are in use so may not apply across the entire District as many blocks are now on multi-space meters. Dome mounted sensors were initially tested in the pilot area along with in-ground sensors, but in-ground sensors were selected for deployment as part of the asset-lite approach.

- **Crowdsourcing** has been used successfully in the transportation industry to identify non-recurring incidents on the transportation network. Several mobile applications have been developed promising to use the power of crowdsourcing to identify occupied and available on-street parking spaces. While the primary focus of these mobile applications is the consumer, the crowdsourced data could also be used by agencies to identify parking occupancy. However, DDOT has not yet had the opportunity to test crowdsourcing applications, so information on their effectiveness is unavailable.

When testing new technologies, the District should test multiple vendors for the same technology to ensure that the District is served by the best in business. To continue to test new technologies and vendors, the District should establish a programmatic mechanism for piloting new technologies through the "sandbox" approach applied during the parkDC pilot. This approach will help ensure effective returns on investment for new occupancy detection technologies. The proprietary system used to blend the different occupancy data sources should be expanded to incorporate new occupancy detection technologies.

6.3.5 Ensure flexible contracting mechanisms

In addition to remaining cognizant of evolving technologies, the District should track evolving business models to ensure that the demand-based pricing program remains relevant and cost-effective. Given the ever-changing nature of the technology landscape, some technologies or vendors that existed when the parkDC pilot began are no longer available, or the vendors' business model has changed to no longer support on-street parking occupancy detection. DDOT contracting and implementation needs to remain flexible and include a preset cost for additional development hours for integration tasks in order for its expanding demand-based parking pricing program to remain relevant and cost-efficient.

6.3.6 Enable Asset-lite payments

Given the high rate of pay-by-cell usage in the District (verging on 95% on some blocks), DDOT has investigated the potential for implementing a pay-by-cell only zone within the pilot area or elsewhere in the District. A pay-by-cell zone could further DDOT's asset-lite approach to curbside parking management by eliminating unnecessary meter infrastructure from a portion of the system.

DDOT has examined existing pay-by-cell usage to identify candidate block faces to include in a pay-by-cell zone, focusing on both the percentage of transactions already made on each block using an app and the percentage of total transactions each block represents for the nearby area. By doing this, DDOT will minimize the impact of a pay-by-cell-only zone to cash-only users. DDOT is considering lessons learned from other parking and transportation programs across the country to ensure that cash-only users will be able to safely and conveniently access meters located near future pay-by-cell zones. Consideration must be given to equity concerns, particularly for customers who may not able to access pay-by-cell (lack of cell phone access, unbanked populations, international travelers) and alternative approaches put in place to ensure those customers can still pay to park easily.

6.3.7 Deploy More Effective Enforcement

Applying data-based analytics to parking enforcement helps guide enforcement towards problem areas or situations. These analytics have the potential to identify areas with regular occupancy challenges and serve as a third lever beyond price adjustment or time limits to address parking supply and demand issues. By capitalizing on access to real-time occupancy and meter payment data, DDOT had hoped to test the efficacy of targeted enforcement. DDOT looked for opportunities during the pilot but was unable to implement the program due to operational challenges. This could be explored further in the future.

6.3.8 Broaden the Applications for the parkDC Model

Along with expanding the parkDC model to more on-street parking spaces in the District, the parkDC team recommends identifying and testing strategies to more effectively manage parking in non-metered spaces. Residential neighborhoods face their own unique parking challenges, and the District should consider strategies such as digital electronic permitting and pay-by-cell zones for parking payments in neighborhoods.

In addition to residential challenges, the parkDC model could be applied to the process for locating disabled parking meters (Red Top meters) and loading zone locations. The District should consider data-driven strategies for enforcing and understanding the parking behaviors of drivers with disabilities and associated loading zone behavior, and other curbside users as those permitted uses change (e.g. motorcoach metering and drop-off/pick-up zones for taxis and rideshare vehicles).

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