CHAPTER 6
Pilot Summary

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

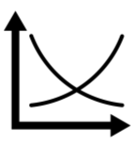
Pilot outcomes specific to the customer perspective can be divided into three levels:

- Direct curbside effects
- Study 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 study area network include:

Table 6-3. Study 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 study area had generally positive trends after the study. 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 study area and Districtwide had generally positive trends after the study. 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 study 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 study 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 study 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 study 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

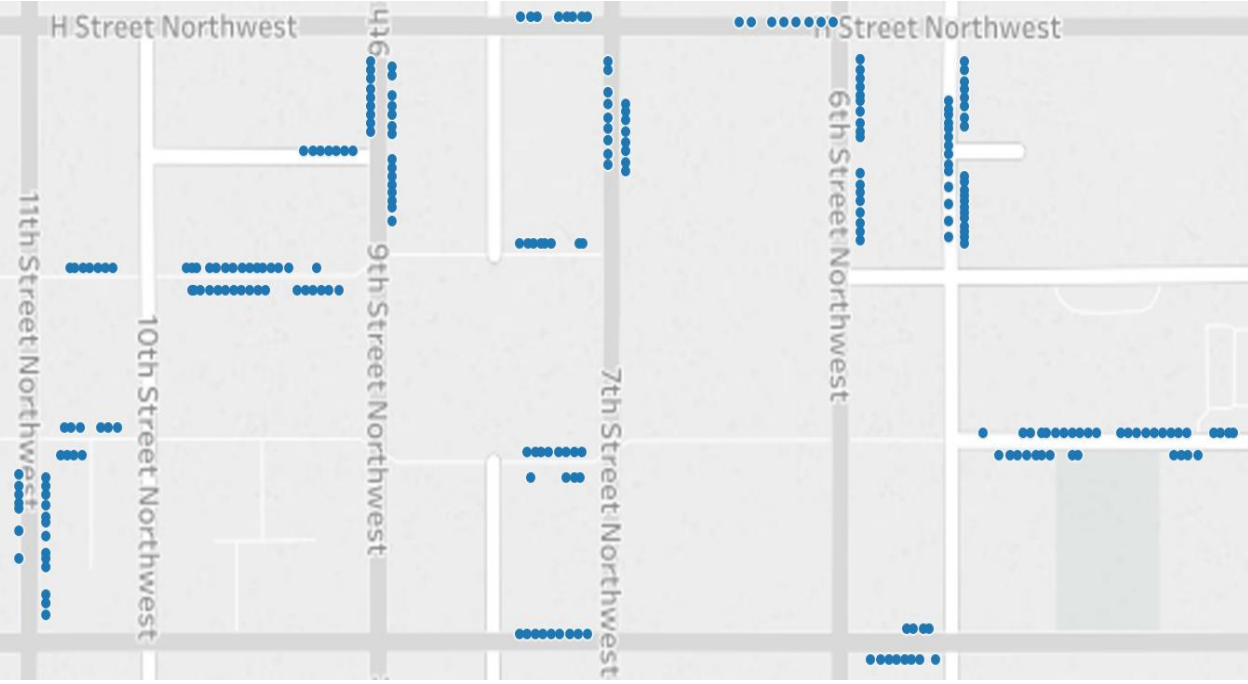
The study area was converted from pay-and-display to pay-by space to improve sensor accuracy, to allow for collection of transaction data at a space level, and to improve the customer experience. Items necessary to convert from the previous pay-and-display environment to pay-by space included:

- 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 study 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 study 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 study 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 study 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 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.

Metric	Finding
Steel construction plates	
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 study 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 study 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 error 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 study 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 study 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.

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

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

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 study 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).