Big Data Analytics Driving Parking Policy:
Evaluating Meter Time Limit Adherence in Washington, DC

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ABSTRACT
This paper provides a case study of how big data analytics can help evaluate the effectiveness of existing policies and formulate new policies. The District Department of Transportation (DDOT) analyzed data on meter time limit adherence, or “overstays” at on-street metered parking spaces beyond the prescribed time limit. This analysis assessed the prevalence of meter overstays, citation patterns, and characteristics of that area. This information could help determine the validity of existing time limits and develop a pricing structure that would shift longer duration parkers to off-street garages. The analysis of overstays was conducted using parking transaction data from DDOT’s pay-by-cell (PBC) program, transactions at networked single and multi-space meters, and parking citation data for overstays. Maps were created to identify areas experiencing historically, chronically, or persistently high rates of overstays. An assessment based on existing land use gauged whether overstays were due to policy flaws (not enough time to conduct business at adjacent land use) or customers trying to game the system because of financial benefits (arbitrage opportunities). Based on the situation, DDOT can consider adjusting time limits, reformulate enforcement protocols, or develop a graduated pricing strategy that minimizes the monetary incentive of parking on–street.

Keywords: Big data, data based policy, parking time limit, parking pricing, parking policy, meter overstay
INTRODUCTION

Located in the crossroads of the U.S. mid-Atlantic region, Washington, DC (DC or the District), is home to over 660,000 residents. As the 22nd largest city nestled within the seventh largest U.S. metropolitan area by population (1), the District is the seat of the Federal Government, and home to a vibrant information and services economy welcoming nearly 600,000 commuters and over 125,000 visitors daily (2). 40 percent of residents and 80 percent of regional commuters who work in the District travel to work by automobile. In addition to tourism and other resident activities, the District has the challenge of providing parking for these vehicles and the demands for parking in traffic generating destinations.

The parking supply in the District is split between privately owned off-street locations (garages, parking pads, etc.) and a finite supply of on-street curb space. The District Department of Transportation (DDOT) is responsible for the management and operation of on-street parking in the District. DDOT, as a unique agency sharing characteristics of both a municipal and state transportation department, manages over 260,000 on-street parking spaces, of which 18,000 are metered parking spaces.

To promote turnover of curb space for consistent access to retail and service destinations and improve traffic circulation in commercial areas, the District uses parking meters (3). Today, the District is facing a complex set of demands for curb space, which intensifies the need for turnover. Since the first meters were installed in 1938 (4), the District has raised meter rates, modified enforcement hours and days, parking time limits, expanded meter installations throughout the District, and upgraded meter technology to meet the increasingly complex curbside management needs.

District’s Parking Meter System Overview

The current on-street metered parking system in the District involves various meter technologies, time limits, meter rates, implementation strategies, and enforcement protocols.

Meter Technology

The District’s meter inventory includes over 18,200 multi-space meter (MSM) spaces as well as network-integrated and traditional single space meters (SSMs) (Figure 1). In an effort to refresh the meter inventory, the District is replacing all traditional SSMs with network-integrated SSMs by the end of 2015. Since 2011, pay by cell (PBC) has been an available meter payment option on all parking meters. Through PBC, users call in and make a payment using their credit card or use a smartphone mobile application to remit meter payment. The overall move to networked integrated technology allows DDOT to log and analyze transaction records as proxy to paid occupancy information.

Time Limits

Within the existing meter inventory, meters have various time limits implemented based on the prevailing land use demands and turnover needs. The prevailing time limit on meters in the District is two hours, with one and four hours the other standard time limits. For motorcycle parking in the District, standard time limits are four and twelve hours. Figure 1 documents the breakdown of the existing meter inventory by programmed time limit.

Meter Rates

The District has three types of meter rate zones, each with their own purpose and meter rates, as documented in Figure 1.
<table>
<thead>
<tr>
<th>Meter Rate Zone</th>
<th>Zone Purpose</th>
<th>Meter Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal Demand Zones</strong></td>
<td>Areas where it is necessary to ensure availability of parking for customers and visitors, such as local neighborhood activity centers outside the Central Business District.</td>
<td>$0.75 / hour</td>
</tr>
<tr>
<td><strong>Premium Demand Zones</strong></td>
<td>Areas with continuous demand for parking spaces to serve the various types of commercial activities in the immediate area, such as Washington’s Central Business District.</td>
<td>$2.00 / hour</td>
</tr>
</tbody>
</table>
| **Performance Parking Zones** | • Protecting residential parking in residential zones;  
• Facilitating regular parking turnover in busy commercial areas;  
• Promoting the use of non-auto transportation; and  
• Decreasing vehicular congestion within each zone.                                                                                     | Variable; Base rate is existing meter rate in area before performance parking rates enacted. | $0.50 / hour |

<table>
<thead>
<tr>
<th>Meter Time Limits</th>
<th>1 hr or less</th>
<th>2 hrs</th>
<th>3 hrs</th>
<th>4 hrs</th>
<th>5 hrs or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>14%</td>
<td>61%</td>
<td>14%</td>
<td>4%</td>
<td>4%</td>
<td>17%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meter Technology</th>
<th>Normal Demand</th>
<th>Premium Demand</th>
<th>Performance Parking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional SSM</td>
<td>1,202</td>
<td>3,494</td>
<td>1,108</td>
</tr>
<tr>
<td>Networked SSM</td>
<td>315</td>
<td>6,789</td>
<td>629</td>
</tr>
<tr>
<td>MSM Spaces</td>
<td>198</td>
<td>2,394</td>
<td>2,100</td>
</tr>
</tbody>
</table>

**FIGURE 1 Washington DC Parking Meter Characteristics**
Implementation Strategies

DDOT implements meters in the District when regulating turnover becomes necessary. Either through a development review process, stakeholder petitions, or from District Council directives, DDOT initiates the review for installing or adjusting meters and their operations. In District regulations, there are general guidelines on the rates and purpose of the meters if installed (as documented in Figure 1) (5). However, time limit designation guidelines are absent in the regulations. To date, DDOT has generally set or changed meter time limits by applying an anecdotal or a reactive approach. DDOT makes changes under one of the following circumstances noted in Figure 2.

**FIGURE 2 Implementation Protocol for Meter Time Limit Designation or Adjustments**

Enforcement Protocol

Meters in the District are enforced by a parking enforcement officers assigned to the Department of Public Works (DPW), DDOT, or the Metropolitan Police Department (MPD). Parking enforcement officers look for vehicles who have not paid for parking (or paid time has lapsed), are oversized for the meter space, parked during restricted hours, or have overstayed the designated time limit for the meter space (5). However, a regulation nuance makes overtime parking enforcement difficult. Language in the regulations defines a parking meter zone as the typical space occupied by a vehicle (in the District this is 20 feet in length) if in a SSM space or as the length of the curb regulated by a MSM or PBC zone. What results in areas served by SSMs is parkers who are overstaying in an area shuffle their vehicles to an adjacent SSM to be legally parked again and not cited for overstaying a meter.

Problem

Parking is already a challenge in a growing and economically vibrant District. Some drivers will park off-street, but others will challenge the intent of parking meters. It does not help that some parkers find parking violations fines low (i.e. overstaying meters are $25, except in Performance Parking Zones where the fine is $50).

Currently the PBC service in the District allows people to start another parking session after the initial parking session has reached the maximum parking duration in the zone. The PBC program does not block a user from overstay.

This paper looks to explore the prevalence of overstaying meters in the District. Within this analysis, the paper also will try to determine if parkers overstaying meters are being incentivized to overstay meters because either (a) the price point for on-street parking is too low or (b) the land use demands and turnover needs do not match the posted time restrictions.

LITERATURE REVIEW

Curbside parking congestion has been an urban problem dating back to the advent of automobiles. The invention and introduction of parking meters in 1935 broached the issue via fixed-rate pricing. Originally, parking meters served the purpose of enforcing time limits for curbside parking, ensuring turnover so that more cars could park in a limited number of curb spaces (6). However, cities quickly realized other methods of enforcing time limits without any fees, putting up various parking signs with specific time limits or other restrictions. Additionally, technological advancements in meters lagged in America with the abundance of free parking spaces (6).
Urbanization led to many transportation problems in American cities, including traffic congestion and more importantly, parking issues. Problems involving parking became critical to cities because cruising for parking \( (6, 7) \) limits the street capacity of traffic and reduces the average traffic speed of adjacent lanes \( (8) \), causing traffic congestion \( (9, 10) \). Some researchers also note that a poor parking policy may even jeopardize the attractiveness of businesses in an urban area \( (11) \) or hinder shoppers and people from doing personal business \( (12) \).

There remains a substantial lack of research in evaluating time limit parking policies. Researchers previously identified parameters of parking decision making, including the price of parking, purpose of trips, accessibility of destinations, and etc. \( (11, 12, 13, 14, \text{and} 15) \) and many researchers claim that on-street parking rates determine the parking dynamics as an easy and second-best approach to regulate demand for parking \( (6, 10) \). In fact, of few, the only research that closely relates to this paper is Thompson and Richardson’s study, which indicates that reducing on-street parking time limits decreases mean in-vehicle travel time and increase walking time \( (16) \). However, lessons learned from applications in collecting and analyzing big data to evaluate operational trends may lend itself to quantitatively evaluate meter overstays in the District \( (17, 18, 19) \).

There are few examples of U.S. cities that do not arbitrarily set time limits or meter rates; municipal (on- and off-street) parking price and regulation setting is a function of the municipal legislative body. Even in cases of implementing curbside performance-based pricing programs such as San Francisco, Los Angeles, and Redwood City, there is limited rationale behind time limits and how a meter zone was delineated \( (20) \). However, in New York City, Indianapolis, and Cincinnati, these cities are experimenting with encouraging turnover by pricing versus arbitrary time limits.

New York City Department of Transportation (NYCDOT) is attempting to improve parking availability from a progressive duration pricing approach with the launch of their PARK Smart Program in Jackson Heights. The idea behind progressive pricing is to increase the price rate the longer someone stays at the meter. NYCDOT found a 67 percent decline in Full-Time (1-hour) purchases and a 38 percent increase in minimum time (15 min.) purchases \( (21) \). The study on Jackson Heights found that with progressive duration pricing the parking occupancy was no longer in critical range \( (< 90 \text{ percent}) \) \( (21) \). The progressive rates have decreased occupancy and average duration in most locations, which allows for more shoppers and visitors to park.

In 2010, Indianapolis formed ParkIndy, a public-private partnership between the city and Xerox, to revamp its parking meter program, optimizing operations through data analytics and predictive modeling \( (22) \). Following the formation of ParkIndy, the time limit policy changed from a two-hour limit during the evening to a four-hour limit on areas with the new meter technology \( (23) \). The new policy allowed visitors and residents to enjoy events in the evening. Concurrently, ParkIndy raised the price of meter parking from 75 cents to $1 an hour, possibly increasing the city’s total meter revenue \( (23) \). Recently, ParkIndy has started removing time limits on underutilized meter spaces. In these underutilized spaces without time limits, paid utilization increased by 18 percent and meter revenue up 22 percent. Following up with customers, ParkIndy found a decline in meter feeding and increase in customer satisfaction with the program \( (24) \).

In 2014, the City of Cincinnati proposed a new on-street parking system proposal, which would add new and replace existing meters with smart meters that include credit card and pay-by-phone capabilities. Much like in Indianapolis, Cincinnati also removed time limits on underperforming meters and found an increase in paid utilization and meter revenue \( (24) \).

METHODOLOGY

The analysis uses nearly 10.5 million approved PBC transactions, 1.6 million SSM, and 2.6 million MSM credit card transactions for the period between January 2014 and June 2015. Meter transaction data is used to conduct this analysis because this data is readily available and malleable to DDOT; parking spaces in the District do not have occupancy sensors, which results in the analysis focusing solely on paid occupancy by proxy data. The analysis will not capture and is not focused on parkers who do not pay to park; this analysis evaluated overstay rates for PBC, MSM, and SSM locations with 2-hour time limits.
Limitations

Before delving into the analysis, some limitations had to be accounted for before commencing the analysis. There were some discrepancies identified in the locational and operational data of the PBC zones and meters to thoroughly evaluate overstays across all of the meter system. DDOT is working with its meter contractor to properly inventory all meter assets and the overlaid PBC zone system to properly convey meter/zone location and their operational characteristics (i.e. time limits, operational hours, etc.).

Coin transactions account for 20 percent of meter revenue. However, without conducting intercept surveys, other data collection efforts, or upgrading the upcoming pay-by-space MSMs to record plate information, there is no other way to track meter overstay transactions by parkers feeding the meter by coin. Moreover, the analysis could not capture the transactions that use two types of payment methods (such as coin and PBC) during overstates.

Lastly, for purposes of meter overstay enforcement, current regulations enforce SSMs as individual parking meter zones versus the block face level at MSMs and PBC zones. What results from this regulatory nuance is one of two things. First, SSM credit card transactions will not detect overstays if a parker moves between SSMs. Secondly, a parker could first use PBC then switch to credit cards at the SSM to pay for parking, which again may not easily be detected as an overstay violation.

Data preparation

Meter overstay is defined as the same vehicle parking at the meter location beyond the posted legal time limit, whether payment is made or not. Without an occupancy sensor or other method to denote when the parking space is vacated, the overstay rate analysis is based on an assumption that the drivers who parked on the meter are actually paying for the entire parking period, whether single or multiple times. The transaction records contain unique meter identifier (zone number for PBC data and meter number for SSM/MSM transaction data), transaction date, start time, end time, parking duration (derived from parking payment divided by meter parking rate for meter), and parker ID (vehicle plate information for PBC data or partial credit card information for SSM data to identify the unique driver). When evaluating overstay citations later in the analysis, citation record contains a citation number, issue date and time, violation code and description of the violation, location of the infraction, and the cited vehicle plate information.

Overstay Rate Calculation

The transaction data is sorted so that all the transactions made by the same vehicle plate, in the same meter zone on the same day would be grouped together to check if there is an overstaying condition. An overstaying transaction is defined as follows:

a) If the parking duration of one transaction record is exceeding the posted time limits, the transaction will be flagged.

b) For multiple records with the same key:

- If time gap between two time-ordered transaction records is less than 15 min, the two transactions are considered as one continuous parking activity by the same vehicle, and the time duration would be summed up together to determine whether the vehicle is overstaying or not.

- If the total parking duration exceeds posted time limits, the transaction, which starts to exceed the posted time limits would be recorded as an overstaying transaction.

- For all meter transactions, records were evaluated for overstay from 7am until the time limit period before 6:30 PM (i.e. a 2 hour zone, would be 4:30 pm; 4 hour zone would be 2:30 PM). Any grouping of transactions’ parking duration does not exceed the time limit before 6:30 pm were not flagged, regardless if the grouping of transactions continues past 6:30pm (5).
- Overstay rate is calculated as the percentage of the number of overstaying transactions over the total number of transactions. A C++ code was developed to run this algorithm.

Figure 3 presents the citywide average overstay rate (2-hour meter zones) for the 18 months period. The average citywide overstay rate for the 18 months period studied is around 11 percent with a range varying from 8.8 percent to 15.1 percent. Based on the analysis findings, the propensity for overstaying is, as described by the Pareto principle (25), driven by fewer zones over time. Additionally, the majority of overstay transactions are via PBC, then MSM, then SSM meters. This is not unexpected given the ease of extending a session remotely using PBC and a parker can just change SSMs or MSMs to not be counted as an overstay.

![FIGURE 3 City wide monthly overstay rate](image_url)

**Emerging Hot Spot Analysis**

To evaluate temporal overstay patterns on the PBC, MSM, and SSM data, the Emerging Hot Spot Analysis tool available on ESRI’s ArcGIS Pro software (Space Time Pattern Mining Toolbox) was used (26). PBC zone, MSM, and SSM locations are geocoded and joined spatially with corresponding overstay transactions. The information has been further aggregates into a data structure with space-time information. The emerging hot spot analysis was performed in a weekly time increment. To filter out data that could skew results, data from loading zones were not analyzed. This data was pulled because the zones only required payment starting in January 2015. Furthermore, motorcycle transactions were also removed since motorcycle parking behavior is significantly different from automobile parking behavior.
The results are shown in Figure 4. Figure 4 highlights PBC, MSM, and SSM overstay patterns in relation to overstay enforcement (enforcement discussed later).

- Maroon spots on the maps signify an area that persistently encounters overstays;
• Bright red signifies an area where overstay (or enforcement) is increasing over time.
• White with a slight red border signifies marginal declines in over stays over time;
• Pink signifies an area that historically has been an overstay hotspot, but the end of the temporal period it was no longer an area experiencing significant number of over stays;
• No color signifies the absence of significant temporal patterns; and
• No significant temporal patterns were detected across the District in relation to MSM transactions.

Land Use Analysis

The emerging hotspot analysis helped identify persistent overstay transaction hot spots. The question now is whether land use plays a role in that behavior. A radius of 250 ft. (typical half block length in Washington) has been applied to detect and synthesize the composition of the immediate land use around the hot spot. This radius accounts for a diameter of a block walking distance; any further would be outside scope of evaluating overstays that is assessed at a block level. Residential land uses were removed from the analysis, since most homes are not major trip destinations for employment, retail, or cultural/recreational activities. Table 1 documents the primary land uses near the observed, persistent PBC and SSM overstay hot spots (no MSM overstay hot spots patterns were observed).

At a macro-level approximately 75 percent of overstays occur near “office” land uses. This would suggest meters near office buildings would be prone to overstay parkers. However, it can only be hypothesized that the majority of parkers near office buildings over staying are commuters gaming the system and minimizing daily parking costs. In theory parkers should be cited for every overstay period (i.e. every two hours), however, the reality could be starkly different. Parking enforcement could be citing parkers once and avoiding additional cites if a previous violation is clearly visible on the vehicle or the enforcement beat of the officer does not take them past the vehicle again. This would perpetuate the parker’s risk assessment arguing in favor of overstaying on-street metered parking.

### Table 1 Land Use Types Adjacent to Persistent Overstay Hot Spots

<table>
<thead>
<tr>
<th>DC Use Code</th>
<th>Land Use Type</th>
<th># Adjacent to Persistent Overstay Hot Spot</th>
<th>Percentage of given land use</th>
<th>PBC or SSM Hot Spot</th>
</tr>
</thead>
<tbody>
<tr>
<td>086</td>
<td>Museum, Library, Gallery</td>
<td>11</td>
<td>1.8%</td>
<td>PBC</td>
</tr>
<tr>
<td>062</td>
<td>Commercial-Garage, Vehicle Sale</td>
<td>17</td>
<td>2.8%</td>
<td>PBC</td>
</tr>
<tr>
<td>067</td>
<td>Commercial-Restaurant</td>
<td>28</td>
<td>4.7%</td>
<td>PBC</td>
</tr>
<tr>
<td>053</td>
<td>Commercial-Planned Development</td>
<td>1</td>
<td>0.1%</td>
<td>PBC</td>
</tr>
<tr>
<td>082</td>
<td>Medical</td>
<td>3</td>
<td>0.3%</td>
<td>PBC</td>
</tr>
<tr>
<td>081</td>
<td>Religious</td>
<td>42</td>
<td>7%</td>
<td>PBC</td>
</tr>
<tr>
<td>051</td>
<td>Commercial-Office-Small</td>
<td>211</td>
<td>35.3%</td>
<td>PBC &amp; SSM</td>
</tr>
<tr>
<td>052</td>
<td>Commercial-Office-Large</td>
<td>238</td>
<td>39.8%</td>
<td>SSM</td>
</tr>
<tr>
<td>032</td>
<td>Hotel-Large</td>
<td>23</td>
<td>3.8%</td>
<td>SSM</td>
</tr>
<tr>
<td>085</td>
<td>Embassy, Chancery, etc.</td>
<td>16</td>
<td>2.6%</td>
<td>SSM</td>
</tr>
<tr>
<td>034</td>
<td>Club-Private</td>
<td>5</td>
<td>0.8%</td>
<td>SSM</td>
</tr>
<tr>
<td>031</td>
<td>Hotel-Small</td>
<td>3</td>
<td>0.3%</td>
<td>SSM</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>598</td>
<td>100%</td>
<td>PBC &amp; SSM</td>
</tr>
</tbody>
</table>

Time Variation Analysis:
To evaluate temporal patterns on a macro level, meter overstay transactions by meter type, month, day of week and time of the day have been counted, as documented in Figure 5.

**FIGURE 5**

(a) Day of Week Variation of Overstay Rates

(b) Time of Day Variation of Overstay Rates by transaction start time*

(c) Time of Day Variation of Overstay Rates by transaction end time*

*Please note that AM Peak: 7AM-10AM, AM No Peak: 10AM-1PM, PM No Peak: 1PM-4PM, PM Peak: 4PM-7PM, Evening: 7PM-10PM, Overnight: 10PM-7AM

Microanalysis in Selected Persistent High Overstay Hot Spots
This analysis dissected a select number of persistent hot spots to identify common land use and parking supply characteristics. Five persistent high overstay hot spots were selected for further scrutiny; three located within the Southeast Capitol Hill neighborhood (zones A,B,C) and two along the H Street NE Corridor (zones D,E). The majority of the hot spot zones selected contain residential land uses mixed with commercial uses, mostly on-street parking, and within walking distance to a metro station. Table 2 describes the selected zone locations as it pertains to geographic location, parking type, and accessibility. Located below, Figure 6 displays the PBC meter overstay transactions by jurisdiction (District, Virginia, and Maryland) for each persistent high overstay rate hot spot. As noted previously, there is no license plate information for SSM and MSM transactions. Across the hot spots, overstay parking is most likely not done by a District resident, who may be weighing risks in favor of overstaying within these areas.

### TABLE 2 Microanalysis on Adjacent Land Use of Selected Overstay Hot Spots

<table>
<thead>
<tr>
<th>Location Boundaries</th>
<th>Land Uses/Neighborhood</th>
<th>Type of Parking</th>
<th>Access to Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Independence Avenue SE, 5th Street, A Street SE and Library Court SE</td>
<td>Predominantly residential with religious and some commercial (banks, restaurants) in the SE Capitol Hill area</td>
<td>Majority of this area is on-street parking with approximately four off-street, residential parking spots.</td>
<td>Nearest metro stations are Capitol South Metro Station and Eastern Market Metro Stations which are approximately 0.5 miles away from Zone A.</td>
</tr>
<tr>
<td>B E Street SE, Pennsylvania Avenue SE, 5th Street SE, and South Carolina Avenue SE</td>
<td>Predominantly residential with a library and some commercial (restaurants, stores) in the SE Capitol Hill area</td>
<td>Majority of this zone contains on-street parking with one small off-street parking lot, approximately 15 total off-street parking spaces.</td>
<td>Nearest metro station is Eastern Market Metro Station, only 0.2 miles away from zone B</td>
</tr>
<tr>
<td>C D Street SE, 8th Street SE, G Street SE, 10th Street SE, and Pennsylvania Avenue SE</td>
<td>Predominantly residential with medical and commercial (restaurant) land uses in the SE Capitol Hill area</td>
<td>Majority of the parking is on-street parking with approximately 20 off-street parking spaces</td>
<td>Nearest metro station is Eastern Market Metro Station, only 0.2 miles away from zone B</td>
</tr>
<tr>
<td>D I Street NE, 13th Street NE, Maryland Avenue NE, and 14th Street NE</td>
<td>Predominantly commercial with some residential land uses in the H Street corridor</td>
<td>Predominantly on-street with one off-street parking lot containing approximately 45 spaces</td>
<td>Nearest metro station is Union Station which is approximately 1 mile away</td>
</tr>
<tr>
<td>E F Street NE, 14th Street NE, G Street NE, and 13th Street NE</td>
<td>Predominantly residential with some religious land uses in the H Street corridor</td>
<td>Majority of parking in zone E is on-street with the exception of one off-street parking lot, which contains approximately 15 spaces.</td>
<td>Nearest metro station is Union Station, which is approximately 1 mile away.</td>
</tr>
</tbody>
</table>
To further assess the phenomenon of overstays, parking citation data from the District Department of Motor Vehicles was reviewed. Data includes the ticket number, issue date and time, violation code and description, location, and plate for the state in which the vehicle is registered. Data was pulled from January 1, 2009 to June 30, 2015.

With the information provided by DMV, data was filtered to pull only parking violations pertaining to meter overtime violations. From nearly 9 million parking citations issued in the past 6.5 years, 299,439 citations were located in reference to meter overtime violations.

Figure 4(d) visualizes temporal citation patterns adjacent to the temporal overstay PBC, SSM, and MSM transactions in Figures 4(a), 4(b), and 4(c). What this comparison shows is that there has been
an increased focus in enforcement in the Central Business District (CBD) in relation to the rest of the District. This is in contrast to PBC overstays occurring persistently to the east of the CBD.

Figure 7 provide a distribution of parking citations by the month, day of the week, hour of the day, or vehicle plate jurisdiction and year of issuance. What is strongly evident in this data is that meter overtime violations is most prevalent among non-District residents earlier in the year (less working holidays), and in the late morning / early afternoon part of the day.

**FIGURE 7 Temporal Overstay Transaction and Citation Patterns in DC (January 2014-June 2015)**

- **Average Number of Overstay Violations 2009-2014: by Day of Week**
- **Average Number Overstay Violations, 2009-2014: by Month**
- **Number of Overstay Violations, 2009-2014: 24-Hour Standard**
- **Number of Overstay Violations, 2009-2014: by Jurisdictions**

**FIGURE 7(a):** Average Number of Meter Violations by Day of Week (2009-2014)

**FIGURE 7(b):** Average Number of Meter Violations by Month (2009-2014)

**FIGURE 7(c) Number of Meter Overstay Violations Hourly (2009-2015)**

**FIGURE 7(d) Number of Meter Overstay Violations by Jurisdiction (2009-2015)**
ANALYSIS FINDINGS

Overstays happen due to a number of reasons. There is a price imbalance between on and off-street parking – this is a classic case in most urban areas. There is a distinct price advantage to parkers by choosing to stay on-street. For a frequent parker, the risk of getting a parking citation ($25) outweighs the price difference between on and off-street parking costs ($2 per hour versus $10 per hour multiplied by the parking frequency). The 11 percent of meter transactions accounting for overstays would be strongly evident across the various persistent hot spots in the Central Business District, where $2 per hour on-street meters compete with $10+ per hour parking garages in a dense employment setting. Drivers from outside the District, prone to overstay, face this paradigm because of trying to minimize higher transportation costs getting to the District (spend the extra time to traverse transit or incur parking and vehicle costs). Drivers in this paradigm lean towards overstaying, considering that (1 the PBC technology makes paid meter overstaying easier despite rules against the practice; and (2 parking enforcement is not likely to issue multiple citations for overstaying as a result of their , despite regulations authorizing them to do so.

Another issue that could cause overstays to occur is that existing meter time limits do not support adjacent land uses. Many parts of the District are undergoing major redevelopment. In some of these areas, off-street parking has yet to be developed, if it is feasible at all, relegating parkers to on-street parking. Historic land uses and past anecdotal analysis may have dictated the existing meter time limits, but they do not match the redeveloped land uses or increased demands evident today (i.e. a former dry cleaner may have dictated a 30 minute time limit, but the location may have been redeveloped into a restaurant, dictating a longer time limit.).

DDOT is considering a range of tactical and strategic initiatives to reduce overstays at on-street spaces. These initiatives run the whole gamut from policy, regulations, pricing, (pay by cell) system refinements and enforcement. This analytic approach can be used by other jurisdictions that want a deeper, measurable understanding of the issue.

NEXT STEPS

Multimodal Value Pricing Project

DDOT initiated a multimodal value pricing project in the Chinatown/Penn Quarter neighborhoods in Washington, DC (27). The project covers 1,000 metered spaces within a 100 block area in a very dynamic and congested downtown neighborhood. DDOT will be applying performance pricing principles by varying pricing by time of day to incentivize parkers to utilize the curb-space for short-term stays and encourage off-street garages for long-term parking. The District can utilize meter transaction data to determine what threshold of demand should be met to trigger a variable pricing program/pilot in other areas of the city.

Time Limit Designation Guideline Development

In early 2015, DDOT started to evaluate its current state of the practice on how it designates parking meter time limits. DDOT realized it had an escalating rate of requests to change meter time limits because of the rapidly redeveloping city. To standardize responses to these requests, DDOT is considering:

- Tying time limits to categories of land uses;
- Placing a temporal moratorium between time limit changes or a significant portion of the land use has changed; and
- Documenting community stakeholder support for those changes.

Refinements to Parking Meter Regulations

Existing parking meter regulations in the District were written at a time when on-street metered parking was limited in technological improvements. When the original regulations were promulgated, SSMs were the only type of meters. Today there are SSMs, MSMs, and PBC zones to regulate on-street metered parking. DDOT is working on revising the regulations to account for meter technology changes. Changes will include how parkers park at broken meters, refining objective and measurable criteria to designate
metered parking zones and time limits. The revisions to the regulations will remove the nuance in
enforcement between meter payment types. The revision would stipulate a parking meter zone, regardless
of meter type, would consist of a block face. Lastly, these changes will allow DDOT to work with the
PBC provider to make operational changes to their service delivery so that a parker cannot automatically
initiate an overstay session.

Targeted Enforcement

The analysis conducted in this paper laid the groundwork for DDOT to provide feedback to District
parking enforcement stakeholders. Continual temporal data analysis could be provided to parking
enforcement to reallocate staffing and resources to start addressing persistent hot spots for overstaying.
Additionally, DDOT can start investigating these persistent overstay hot spots to determine whether meter
time limits need to be adjusted.

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