BIPARTISAN POLICY CENTER

IMPROVING
THE VOTER EXPERIENCE

Reducing Polling Place Wait Times by Measuring Lines and Managing Polling Place Resources

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Introduction

Long lines at the polls can undermine the voting experience, even to the point of discouraging people from voting. Long lines and the wait times that ensue are not only problems in and of themselves, but they can be symptoms of other underlying problems in the voting process. That's why, after the 2012 election, President Barack Obama singled out long lines as a problem that the United States should fix and cited it as the first order of business for the bipartisan Presidential Commission on Election Administration (PCEA), which he launched in early 2013.

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"Long lines and wait times at the polls are not only problems in and of themselves, but can be symptoms of other underlying problems in the voting process."

As soon as President Obama shone a light on the problem of long lines at polling places, it quickly became clear that little was known about polling place lines: where they occurred, how often they occurred, and why they occurred. However, the PCEA initiated a host of studies and collaborative projects that have helped fill in the knowledge gaps about polling place lines. This report summarizes many of these efforts and highlights the actionable knowledge they have produced with seven major takeaway points.

MAJOR TAKEAWAYS

1. Lines at polling places can be studied—and brought under control—by using approaches and tools that businesses have been employing for decades.

These tools, part of "queuing theory," are used in an astounding array of settings, from designing the set-up of checkout stations in grocery stores to designing the flow of electrons through a computer. Luckily, the core principles of queuing theory are intuitive and can be implemented using simple applications and procedures.

2. To effectively manage polling places and reduce lines, election officials must collect information about the number of people in line on a regular basis at every polling place in their jurisdiction.

The Bipartisan Policy Center's project to promote the recommendations of the PCEA has developed a procedure that relies on collecting information about the number of people in line on an hourly basis. This procedure was used by 88 jurisdictions in the 2016 general election, and it proved to be easy to implement. BPC and MIT's Election and Data Science Lab worked together to provide each participating county with detailed reports about wait times at their polling places; most importantly, election officials used this information to identify problematic polling places and unwieldy wait times, and to design specific solutions to reduce lines. The most important takeaway from the effort is that collecting hourly line data at every polling place is a best practice that should be adopted by every jurisdiction in the country. This level of attention to how voters flow through polling places is specific enough to effect meaningful change to operations at polling places.

3. Long lines can be reduced through best-practice management techniques and policies that encourage a smooth flow of voters in polling places.

The number of voters who waited longer than the PCEA's benchmark of 30 minutes fell between 2012 and 2016. More significantly, states that had the longest wait times in 2012 saw the biggest improvements in 2016. These improvements were the result of multipronged efforts by election officials and legislators, and they demonstrate that the application of simple line-management techniques can produce significant benefits for voters.

4. Long lines are not the norm for most voters, but at a substantial fraction of polling places, voters wait longer than the 30-minute PCEA goal; and at a smaller but still troubling group of polling places, lines can stretch over one hour.

Public-opinion surveys have shown that the vast majority of voters do not face long lines. In 2016, 74 percent of respondents to the Survey of the Performance of American Elections reported waiting 10 minutes or less to vote, and 92 percent said they waited 30 minutes or less. Some voters nonetheless waited more than the PCEA's 30-minute goal: 7 percent reported waiting 30 to 60 minutes, and 1.8 percent reported waiting over one hour. The local jurisdictions that participated in the BPC/MIT study saw similar distributions of wait times in the precincts that were studied: 74 percent of polling places had an average wait time of 10 minutes or less; 92 percent of precincts had an average wait time of 30 minutes or less. Eight percent of precincts exceeded 30-minute goal set by the PCEA, with 4 percent of precincts reporting a 30- to 60-minute wait time and another 4 percent reporting an average wait time of over an hour.

5. Lines can be caused by issues that are unique to a polling place or by more general problems relating to chronic capacity shortages.

Long lines can be caused by a sheer lack of capacity to deal with the crowds who come out to vote, or they can be caused by unexpected events, such as a power outage, sick poll workers, or broken voting machines. Regardless of why long lines occur, the proper documentation of line lengths on an hourly basis is essential to identifying the problems and finding solutions.

6. Lines are longest on the morning of Election Day.

While a commonly told story about elections is that there are two peaks of voting, early in the morning and late in the day, the BPC/MIT study found that the greatest crush of voters tended to arrive in the morning and create long lines at the start of the day. This finding was consistent across many counties and many states. There were exceptions to this common pattern, of course, and careful measuring of each polling place is still needed to determine exactly when the bottlenecks emerge. But as a general matter, to the extent that election officials can allocate resources to address this morning crush, they will have more success keeping down wait times.

7. Longer lines are correlated with larger precincts; precincts unable to handle early morning lines; and precincts that are more urban, dense, and have higher minority populations.

Precincts with large numbers of registered voters often have too few check-in stations or voting booths to handle the volume of voters assigned to the precinct, even under the best of circumstances. Precincts that are unable to clear the lines from the first three hours of voting are virtually guaranteed to have long lines throughout the day. Polling places in urban areas often face design challenges—small, inconvenient spaces—that undermine many election officials' best efforts to provide adequate resources to these locations.

PCEA: "The Line Commission"

Early one morning in 2012, 102-year-old Desiline Victor waited three hours to cast her vote in Miami-Dade County, Florida. This iconic example of long wait times, however, was not unique; news media reported numerous instances of long lines at polling places across the country. Obama took note of the polling place line problem in his postelection speech, declaring to the country, "We have to fix that." Several months later, he announced the creation of the PCEA to improve election administration. Reducing polling place lines was not the only subject of inquiry for this commission, but lines were the first concern, and the commission came to see lines as a symptom of deeper problems in the election administration system that needed to be addressed.

The PCEA was bipartisan. Experienced election lawyers who had represented their respective parties and party candidates for many years served as the co-chairs: Robert Bauer had served as general counsel to the Obama 2008 and 2012 campaigns and as President Obama's White House counsel, and Benjamin Ginsberg had served as general counsel to Mitt Romney's 2012 campaign. In addition, the commission included five election officials at the state and local levels and several commissioners with private-sector backgrounds.

Among the commission's numerous recommendations was a concrete, 30-minute standard by which to judge the length of lines at polling places: "As a general rule, no voter should have to wait more than half an hour in order to have the opportunity to vote." The PCEA also made public a set of tools for election administrators to estimate capacity needs in order to keep lines to manageable lengths. In fact, many of the recommendations to improve the voting process are themselves likely to be useful to addressing the lines. For example, improvements to the voter-registration system could reduce voter confusion and check-in problems, and ultimately reduce time spent at a polling place. Jurisdictions were also encouraged to explore alternate voting methods, such as early voting and voting by mail, that could reduce the crush of voting on Election Day.

After the conclusion of the PCEA's work, the commissioners asked BPC to continue working on their recommendations. The Caltech/MIT Voting Technology Project (VTP) also worked on the commission's recommendations, particularly those pertaining to long lines and wait times. The VTP had already responded positively when the PCEA asked it to develop a special website—one that would host online tools to help election officials match polling place resources (such as poll books and voting machines) to the expected volumes of voters on Election Day. Ultimately, BPC and the VTP collaborated to develop a line-management program for local election jurisdictions and to provide technical support and advice.

Why Worry about Polling Places Lines?

Pictures of polling place lines are a cliché of Election Day news coverage. In emerging democracies, long lines at the polls are often viewed as a tribute to the people's faith in the promise of self-governance. In a long-established democracy such as the United States, a long line is seen as something else: a failure of election officials to adequately plan for the election. In reality, long lines are not always a sign of failure. For instance, long lines are inevitable if voters queue up at the polling place before the voting hours begin. Still, there are better and worse ways for election officials to handle the surge of voters that can occur, especially in presidential elections. When local officials don't plan appropriately, they impose unnecessary inconvenience and monetary costs on voters. Long lines may be a canary in the coal mine, indicating problems beyond a simple mismatch between the number of voting machines and voters, such as voter rules that are inaccurate or onerous. Furthermore, there is evidence that when voters see long lines at a polling place, regardless of the reason, they are discouraged from voting themselves.

VOTER INCONVENIENCE AND COST

The most obvious problem of long lines is voter inconvenience. Voters who spend an hour waiting to cast a ballot may face conflicts with other daily activities and annoyance with the process. But, long lines do more than inconvenience the voters standing in them. One estimate of the economic costs of waiting to vote places an economic value of waiting in line at over half a billion dollars in a presidential election.[1] Unsurprisingly, people who wait a long time to vote are much less likely to be confident that their votes will actually be counted.

DISCOURAGEMENT FROM VOTING

Long lines cost votes. Relying on responses to the U.S. Census Bureau's Current Population Survey, the VTP estimated that in 2000, half a million citizens failed to vote because of long lines and other polling place problems.[2] Repeating this analysis using 2016 data reveals that this number dropped, but only somewhat. Evidence about people being discouraged from voting due to long lines comes not only from surveys, but from direct observation. In 2016, a nationwide study that involved sending student researchers to hundreds of polling places to observe the dynamics in polling place lines found that about 3 percent of people standing in line left the line before they were able to vote.[3] It isn't clear whether these voters returned to vote at another time, but certainly lines drive some voters away. In addition, the perception that there will be long lines may cause some voters to stay away from the polling place to begin with.

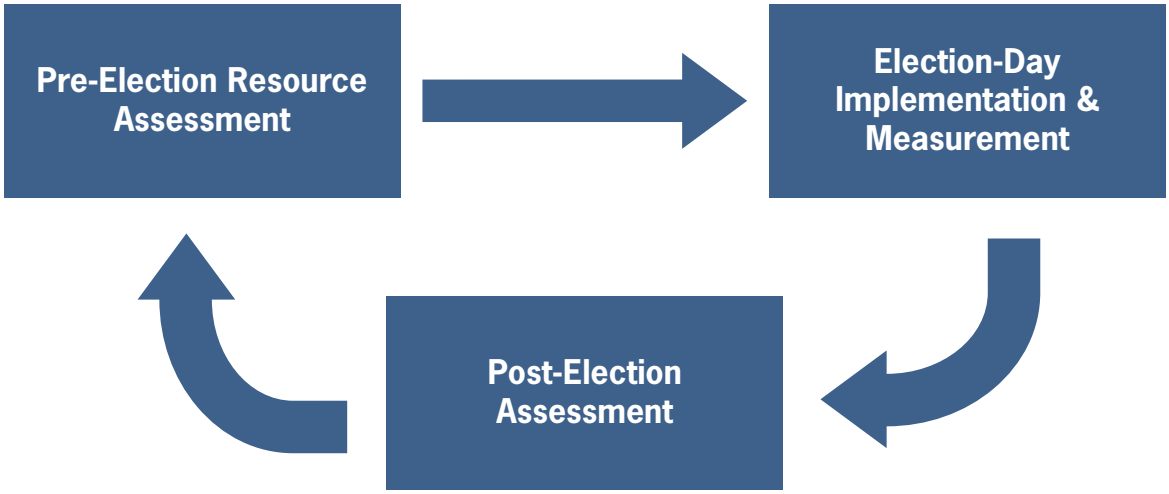
LINES MAY BE A SIGN OF PROBLEMS WITH ELECTION ADMINISTRATION

Polling place lines are a sign that something has gone wrong with the administration of the election. What precisely went wrong is the important question. Sometimes lines will form because the necessary resources—staff, voting machines, poll books, etc.—have not been assigned to a polling place to meet the known needs of that location. In other cases, lines will form because of onetime unanticipated events, such as a malfunctioning electronic poll book, a power outage, etc.

Efforts to Combat Long Wait Times

Combating long wait times requires a process of planning, monitoring, and assessing that is common in all areas of public policy (See Figure 1). *Before the election*, officials must assess whether the resources devoted to polling places—poll books, poll workers, ballots, voting machines, etc.—are adequate to handle the quantity of voters expected to arrive on Election Day.[4] *On Election Day*, they must measure lines and wait times in order to see whether the pre-election plans were adequate and to understand where any unanticipated problems might emerge. *After Election Day*, they must reassess their previous plans as they anticipate the next election.

Figure 1: The Planning Cycle for Election Resource Management



Source: BPC Voting Lines Project

Over the past five years, BPC and MIT helped state and local officials undertake every step of this planning cycle. Some of these efforts were conducted separately, while others were done in partnership. Taken as a whole, they constitute a comprehensive program that can be used by officials to improve the experience of voters.

PLANNING RESOURCE ALLOCATION USING ONLINE TOOLS

Even while the PCEA was still meeting, the commission asked the VTP to publish a set of online tools to help state and local officials know how they should allocate polling place resources in order to keep lines within manageable parameters. All of these tools were based on established methods, some of which had been used by the private sector for over half a century.

The tools are described in more detail in the VTP's report, *Managing Polling Place Resources*, and are available via the VTP's website, *web.mit.edu/vtp*.[5] Two tools bear special mention. The first, developed by MIT researchers Prof. Stephen Graves and Dr. Rong Yuan, allows election administrators to enter three basic parameters into a spreadsheet, which then calculates the amount of resources (e.g., voting machines and poll books) that are necessary to keep wait times down to a manageable number. The three basic parameters are the anticipated turnout, the average amount of time it takes to vote (or check in, depending on the part of the process being planned), and the target maximum wait time. The second tool, which was originally developed by Prof. Mark Pelczarski for the Obama campaign in 2012, allows administrators to use information similar to that on the Graves-Yuan spreadsheet, *plus* information about the patterns that describe when voters arrive during the day.

Both tools were used by a large fraction of election jurisdictions around the country before the 2016 election. In a postelection survey of local election officials, roughly one-third of officials reported consulting these tools as they planned for 2016. The VTP website also includes videos to help officials learn how to use the tools for planning.

MEASURING PERFORMANCE ON ELECTION DAY

During the 2014 and 2016 elections, projects organized by BPC and MIT studied polling place dynamics using a variety of techniques. At MIT, one of these projects took a distinctly academic approach. One protocol allowed voters to be timed in minute detail as they completed all the tasks associated with voting, such as checking in, marking a ballot, and scanning a ballot. Arrivals and line lengths were measured on a real-time basis. These protocols were implemented by armies of researchers, mostly students, under the supervision of faculty members. Research teams were deployed throughout the country.

These academic programs were important for two reasons. First, they helped to establish the relevance of queuing-theory models to elections. Second, they helped in the development of streamlined models of Election Day data-gathering that could be used outside the academic setting.

The most extensive of the academic studies occurred during the 2016 election, when faculty members and students from more than 20 academic institutions fanned out across the United States for the most extensive study of polling place dynamics ever attempted. The student researchers involved in this effort visited nearly 600 precincts coast to coast and recorded how many voters were standing in line and how many voters had arrived to vote within 10-minute intervals. They also observed how long it took nearly 8,000 voters to complete all the tasks associated with voting, ranging from checking in to scanning their ballots.

This type of academic study, in which polling places and voters are observed in minute detail, are very important for advancing scientific knowledge about polling place resource deployment, but they are not the types of studies that election officials are likely to undertake on their own. These studies are very labor intensive, both in gathering the data and overseeing the researchers. However, these academic studies suggest ways that protocols could be streamlined and made relevant to local election officials. In the next section, we describe the streamlined program that was developed jointly by the BPC and MIT.

ASSESSING PERFORMANCE AFTER THE ELECTION

After the election, it is important for local officials to see whether the predictions of the planning models, plus any other factors that went into planning for Election Day, were borne out. If lines were much longer than expected, it is important to understand why that happened.

Researchers in the BPC/MIT program found that precincts usually performed as predicted, given the planning models, but that there were always exceptions. The exceptions were usually due to unanticipated events, such as a malfunctioning electronic poll book or an unanticipated busload of voters arriving at an already-busy moment.

The BPC/MIT Program

MIT and BPC joined together to create a program with a simple goal: to provide local election jurisdictions with actionable data about the lines that formed at their polling places, mostly on Election Day, but in some cases, during early voting as well. The BPC/MIT program was informed by the academic projects described in the previous section, but it was designed with one important constraint in mind: The method of collecting data had to be simple and easily implemented by poll workers. To that end, researchers developed a simple coding sheet and a set of instructions that helped poll workers record the number of people standing in line during every hour of the voting day.

All told, 88 jurisdictions participated in the program, ranging from Oscoda County, Michigan (roughly 6,800 registered voters) to San Diego County, California (3 million registered voters).

Simply knowing how many people were standing in line each hour was extremely valuable. Most jurisdictions had never conducted a project like this and instead had relied on anecdotes to develop an understanding of line dynamics.

For just a little bit of added effort, many counties were able to provide another set of data that made the line counts even more valuable. This was data about the number of people who checked in to vote each hour at each polling site, as well as the number of check-in stations employed at each polling site. For counties that use electronic poll books, it was easy to provide this information. Combining the e-poll book data with the line counts allowed researchers to show the jurisdictions even more about line dynamics, including arrival patterns and wait times calculated at intervals during the day.

The BPC/MIT program was designed to be extremely simple to implement; it was also designed to be mindful about not adding too much extra time and effort to a poll worker's already-busy job description. Researchers estimate the amount of time that a poll worker spent collecting line information was less than one minute at the top of each hour. The poll worker simply had to count how many people were standing in line to check in and record that single number on a handwritten sheet along with the number of poll books available to be used at that time. The poll worker performed this task at the time the polling place opened and then at the top of every hour the polling place was open. A typical data-collection form is shown in Figure 2.

Figure 2: Example of Data Collection Form for BPC/MIT Polling Place Line Study

Line Length Data Collection Sheet
Hanover County, Virginia
November 8, 2016
General Election

Envelope #8

Precinct number/name: 105 BERKLEY

Instructions. Please use this sheet to record the number of people standing in line to check in to vote at the indicated times, along with the number of poll books available to accept voters to check in.

If there is no one standing in line at the indicated time, please enter a zero ("0").

If you are unable to record the line length at a particular time, enter an "X" in the corresponding space.

Time	Number in line	Number of poll books
When polls open*	35	2
7:00 a.m.	14	2
8:00 a.m.	18	2
9:00 a.m.	5	2
10:00 a.m.	28	2
11:00 a.m.	19	2
12:00 noon	0	2
1:00 p.m.	1	2
2:00 p.m.	1	2
3:00 p.m.	0	2
4:00 p.m.	3	2
5:00 p.m.	2	2
6:00 p.m.	3	2
7:00 p.m.	0	2

At what time did the last voter check in to vote? 6:59

*If the polls opened at some time other than 6:00 a.m., indicate that time here: NA

Source: BPC Voting Lines Project

At the end of Election Day, the participating counties collected all of the sheets from their polling places and sent them to MIT. MIT then keyed in the data and produced an individualized report for each county. After Election Day, MIT gathered data about the number of voters who turned out in person at each of the polling places in the study. (This information was easy to gather from the reports issued by the local jurisdictions in the course of canvassing the election results.)

Each local jurisdiction received a report that contained at least two parts. The first part was a cleaned spreadsheet of the data that had been collected on the paper coding forms. The second part of the report calculated the average line length during the day; also, by using turnout information, the report calculated the average wait time to vote at each precinct in the jurisdiction. (See below for a discussion on how this calculation was performed.)

Figure 3 shows an example of this kind of report. Election Day turnout was based on official reports published by the local jurisdictions, and the arrivals per minute were calculated simply by dividing Election Day turnout by the number of minutes the polls were open during the day. Average line length was calculated directly from the observational data provided by the counties. The average wait time for each precinct was calculated using Little's Law, which is described below.

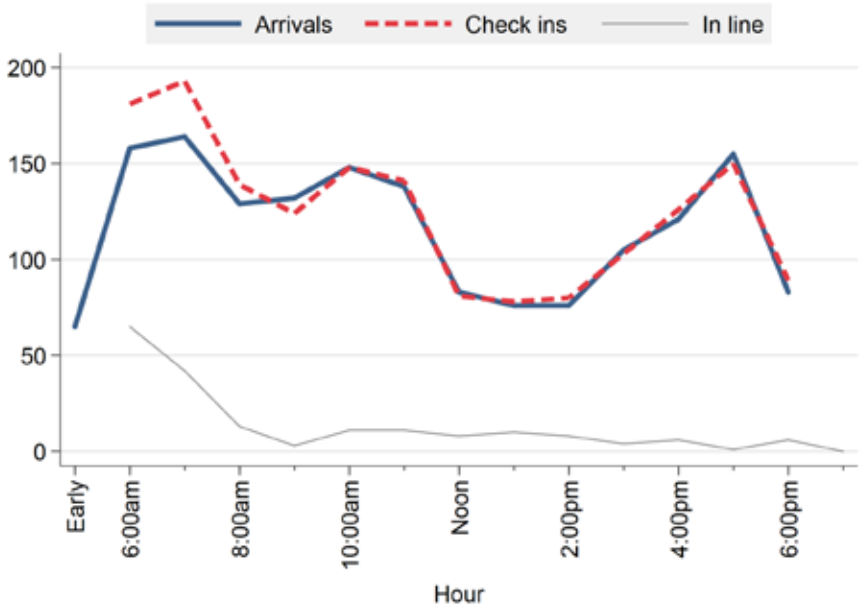
Figure 3: Example of Precinct Wait-Time Report Received by Participants in The BPC/MIT Polling Place Line Study

Precinct	Election Day Turnout	Average Line Length	Arrivals Per Minute	Average Wait Time (Min.)
001 - ONE	1548	10.4	2	5.3
002 - TWO	1445	5.4	1.9	2.9
003 - THREE	2006		2.6	
004 - FOUR	1611	6.4	2.1	3.1
005 - FIVE	1400	6.5	1.8	3.6
006 - SIX	1467	8.6	1.9	4.6

Source: BPC Voting Lines Project

Counties that were able to provide hourly data about voter check-ins from their e-poll book systems received an additional report. This report calculated how many voters had arrived at the polling place each hour. The details of the report each jurisdiction received is illustrated by the graph in Figure 4, which displays the data provided by the county for one particular precinct—the line length at the start of each hour (the solid gray line) and the number of check-ins (the dashed red line). In addition, it was possible to use a little algebra to calculate when the voters arrived (the bold solid blue line).

Figure 4: Example of Graph Showing Hourly Arrivals, Check-Ins, and Number Standing in Line for One Precinct



Source: BPC Voting Lines Project

The polling place line program can be considered a success based on a variety of metrics. Dozens of jurisdictions and thousands of precincts were involved in the project. The data-gathering protocol was simple enough that almost all jurisdictions reported that it was easy to train poll workers; for the most part, the data collected by the poll workers was accurate and usable. The reports returned to the jurisdictions provided both a broad overview of the line dynamics throughout the counties and allowed local election administrators to drill down into specific precincts where problems emerged.

BPC assisted jurisdictions conducting this program by recruiting participants and coordinating the nationwide program. MIT provided data entry and reporting. (A few jurisdictions entered their own data, for which both BPC and MIT were grateful.) While a similar arrangement is anticipated for the 2018 election, it is anticipated that over time, the local jurisdictions will take on the responsibility for data entry and analysis themselves. The simplicity of the data-gathering protocol and the resulting analysis should make it possible for any local jurisdiction in the future to conduct this program on its own.

Little's Law: The Science Behind the Line-Length Program

A long line out the door of a precinct on Election Day may be the most visible sign that something is wrong with the administration of a polling place, but a long line is not, in and of itself, the problem. The problem is the *wait* a long line can create. Everyone has experienced a short line that takes forever to move. (Think about the last time you were at a customer-service desk with a difficult customer in front of you.) And, everyone has experienced a long line that moves quite quickly. (Think about the line of 100,000 people that can exit a football stadium in a matter of minutes.) Ultimately, what everyone really wants to know is not the length of the lines at polling places, but how long voters have to wait to check in and get a ballot.

Intuition suggests that there is only one way to measure how long a voter waits in line to get a ballot: Follow every voter who gets in line to vote and use a stopwatch to time how long everyone waits. (For efficiency's sake, researchers or election administrators might want to time a sample of voters, but the underlying intuition remains the same.)

There are two problems with this intuitive approach. First, it is very labor-intensive and inefficient. There are tricks that can be applied to make this approach more efficient, such as following only a sample of voters or giving arriving voters time-stamped cards that are turned in when they reach the front of the line. But at the end of the day, timing individual voters takes a lot of planning and a lot of work to execute properly. For this reason, direct timing of voters, when it is done at all, is typically done only by the largest election jurisdictions.

The second problem with the intuitive approach is that there is a much simpler procedure that can accomplish the same goal—and can accomplish it just as accurately. This procedure, which has been taught in business schools for over half a century, requires that only two quantities be calculated per precinct: the average arrival rate of voters on Election Day and the average line length. (If one is calculating wait times during early voting, the same applies for each day of early voting at a particular location.)

These two quantities, average arrival rate and average line length, can be plugged into the following formula, to produce the average wait time:

$$\textbf{Average Wait Time} = \frac{\textbf{Average Line Length}}{\textbf{Average Arrival Rate}}$$

This formula is an adaptation of Little's Law, which is the most fundamental equation in queuing theory. (Queuing theory is the scientific study of waiting in lines. It has many applications beyond managing things like ticket counters and polling places, such as inventory control, managing call centers, and designing computer chips.)

Every election official in the United States already knows—or should know—the denominator in the formula: the average arrival rate. The average arrival rate is simply the number of voters divided by the number of hours the polls were open—or, more accurately, the number of hours that voters were allowed to arrive and get a ballot. (For instance, if polls are open in a state from 8:00 a.m. to 8:00 p.m., but a long line at the end of the day means that the line at a polling place doesn't clear until 9:00 p.m., the number of hours open is 13, not 12.) If 1,200 voters vote during a 12-hour Election Day, then the average arrival rate is 100 voters per hour.

Every election official in the United States *does not know*—but should know—the numerator in the formula: the average line length. The average line length is the number of people in line on a regular basis, divided by the number of times the line was counted. BPC and MIT's line-length program provides a simple way for local jurisdictions to gather the data necessary to calculate the average line length during a day.

There is one very important caveat about the use of Little's Law to calculate the average wait time at a precinct. Little's Law is true *over the long run.* That is, it works only if the averages are taken over a long period of time and if enough data has been gathered to make the *calculated* average line length close to the *actual* average line length.

What this means is that Little's Law is absolutely accurate if voters are arriving at a steady pace (on average), and if someone is constantly recording how long the line is. It becomes subject to statistical variability if the line isn't monitored constantly. Thus, there is a trade-off between precision and cost in using Little's Law to calculate wait times in real-world environments.

The protocol developed for BPC and MIT's line-length program strikes a workable balance between precision and cost. By recording the line length on an hourly basis (including the moment the polls open), it is usually possible to calculate the average line length using 13 or 14 observations for each precinct. If line length were recorded more frequently—say, every half-hour—the calculated average would be more accurate, because there would be twice as many observations. But, this would take more work and could potentially distract poll workers from other important tasks. Hourly data-gathering strikes the right balance.

For jurisdictions that also record check-in statistics on an hourly basis, it is possible to use Little's Law to estimate wait times during narrower windows during the day. That's because the check-in data allows one to calculate when voters arrived during each one-hour period of the day. With this information, researchers and election officials can gain more precise knowledge about wait times during the day.

Consider the following example, which is summarized in the table below. There is a precinct that has 1,200 voters during a 12-hour voting day that stretched from 8:00 a.m. to 8:00 p.m. With an average line length of 9.9 and 100 voters arriving, on average, each hour, the average wait time is calculated to be six minutes.

Table 1: Example of Polling Place Line Calculations

	8:00 a.m.–2:00 p.m.	2:00 p.m.–8:00 p.m.	Total
Average line length	17.0	1.4	9.9
Average arrival rate	128.6	66.7	100.0
Average wait time	0.13 hr. (7.8 min.)	0.02 hr. (1.2 min.)	0.10 hr. (6.0 min.)

However, more people arrive during the first half of the day, creating longer lines, than in the second half. If the day is split in half, researchers can recalculate the average line lengths and arrival rates for each half. Doing so, it becomes clear that the average wait time during the first half of the day was 7.8 minutes, going down to 1.2 minutes during the second half.

The Results of the BPC/MIT Line-Length Program in Depth

Clearly, long Election Day lines can be managed in a variety of ways. To take a narrower focus, it's valuable to examine the results of the BPC/MIT Line-Length program—who participated and what can be learned generally from the data that were gathered.

It is important to note that the sample of participating jurisdictions was not a random selection of local election jurisdictions across the country. Therefore, it cannot be taken as the definitive study of nationwide wait times in the 2016 election. However, the demographic (and other) characteristics of the participating jurisdictions are very similar to the characteristics of local jurisdictions nationwide. Therefore, though these current findings cannot claim to be representative of the whole nation, they are not likely to be too far afield from a national data set.

WHO PARTICIPATED IN THE PROGRAM?

Over 100 counties engaged with the BPC/MIT line-length program in 2016, of which, 88 produced Election Day line data that was usable for this report. The current goal is to at least double participation in 2018.

The initiative began with several pilot counties in the 2014 general election and subsequent primary and general elections leading up to 2016. Fairfax County, Virginia, which had been the subject of one of the first academic studies described above, was the first county to participate in the BPC/MIT program during the 2014 election. Fairfax County volunteered to pilot the program in 2014 only a few weeks before the election. The ease of integrating the program into the county's training and Election Day procedures was compelling evidence that the program would be relatively easy to implement at scale. Other early adopter counties included Broward County, Florida; Orange County, Florida; Seminole County, Florida; Richmond County, Virginia; and Montgomery County, Maryland.

The 88 jurisdictions that provided usable polling place line data in 2016 are listed in Appendix A.

These jurisdictions covered a broad swath of the United States. By the numbers:

- 11 states
- 15,644,645 registered voters
- 11,059,900 votes cast, or 8 percent of nationwide turnout[6]
- 4,006 precincts

All told, the jurisdictions provided more than 56,000 hourly records of line-length data.

Although the jurisdictions that participated in the program were not randomly chosen, they are nonetheless demographically quite similar to the nation writ large. Racially, the precincts in the study are a near-perfect match to the nation. The precincts are in areas with slightly more college graduates and slightly less poverty than the nation as a whole. And the precincts are located in towns that are slightly more densely populated than the rest of the nation. Prior research has shown that wait times are routinely longer in densely populated areas.[7] Therefore, the average wait times encountered by the jurisdictions covered by this program were probably greater than the national average wait times, but only somewhat.

Table 2: Demographics vs. Catalist Data

Attribute	Sample	Nationwide
White	75.9%	74.5%
Black	11.7%	11.9%
Hispanic	8.2%	9.5%
Other race	4.2%	4.1%
Over 65	24.1%	24%
College graduates	34.8%	27.9%
Living in poverty	9.2%	12.6%
Renters	11%	12.8%

Source: Sample conducted by BPC Voting Lines Project; Nationwide data from Catalist

Not all counties were able to provide hourly check-in data; thus, any findings that focus on arrival patterns are weighted toward those jurisdictions that could, which were primarily located in Florida and Virginia. Finally, two counties provided information about early voting patterns, Dallas County, Texas, and Wakulla County, Florida.

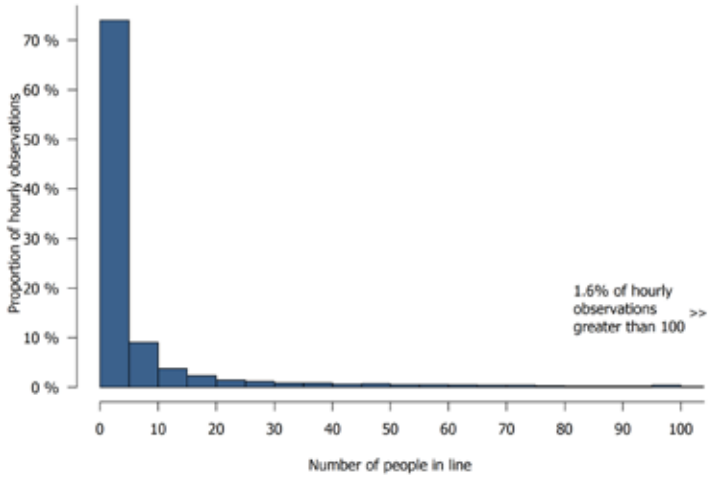
FINDINGS

There were eight main empirical findings that are important to emphasize.

1. The average number of people in line at any given time was 9.3. However, this average masks an important detail: Most lines were very short, but a few were very long.

The graph in Figure 5 shows the distribution of the number of people standing in line each hour for the precincts that were included in this study. The average line length was 9.3. However, this average is strongly influenced by a small number of precincts that experienced incredibly long lines. The median number of people in line was just two people—which means that half of the hourly line counts were longer than two and half were shorter than two. Finally, the most common number of people in line at any hourly observation was zero. In all, just over one-third (35 percent) of all the recordings in the data had nobody in line at all.

Figure 5. Distribution of All 56,000+ Observed Hourly Line Lengths Across 4,229 Voting Locations in 2016 Election



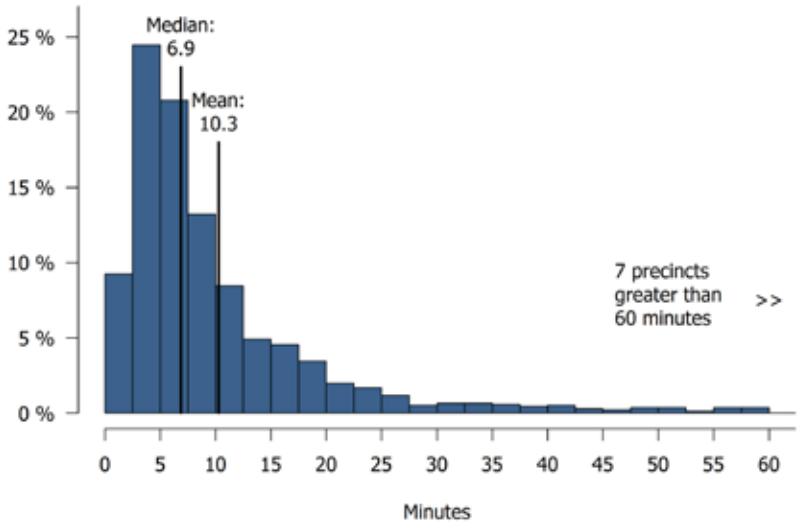
Source: BPC Voting Lines Project

A major challenge of running an election is not about understanding how long lines will be *on average*. Instead, election officials must account for how long the line will be *at its worst*. Another way of exploring the line-length data is to ask how long the *longest* line was for each precinct in the sample. For roughly two-thirds of precincts (68 percent), there were 10 or more people in line at least once during the day. Put another way, one-third of precincts never had more than 10 people in line throughout the entire time it was open.[8] Meanwhile, 43 percent of polling locations had a line of at least 25 individuals. A quarter (25 percent) experienced a line of 50 or more people during the day. Finally, just one in 10 precincts (11 percent) had more than 100 people standing in line to vote at least once during the day.

2. The average wait time for precincts in the study was 10.3 minutes. This, too, is influenced by the small number of precincts with very long average wait times.

In all, there was enough data to calculate the average hourly wait time in 32 percent of the precincts in the study (1,361 out of 4,229). Figure 6 shows the estimated average wait time for voters in these polling places. In most areas, lines were typically very short. The mean wait time across these precincts was 10.3 minutes, and the median wait was just 6.9 minutes. Just over two-thirds (68 percent) of precincts had an average wait of less than 10 minutes. These findings are largely consistent with survey-based estimates of average wait times from the 2016 election, which found that 71 percent of voters waited less than 10 minutes to vote.

Figure 6. Average Wait Times in 1,361 Polling Places



Source: BPC Voting Lines Project

However, some areas had much longer waits. At the high end, one out of 20 (6 percent) precincts had average waits that were longer than 30 minutes.

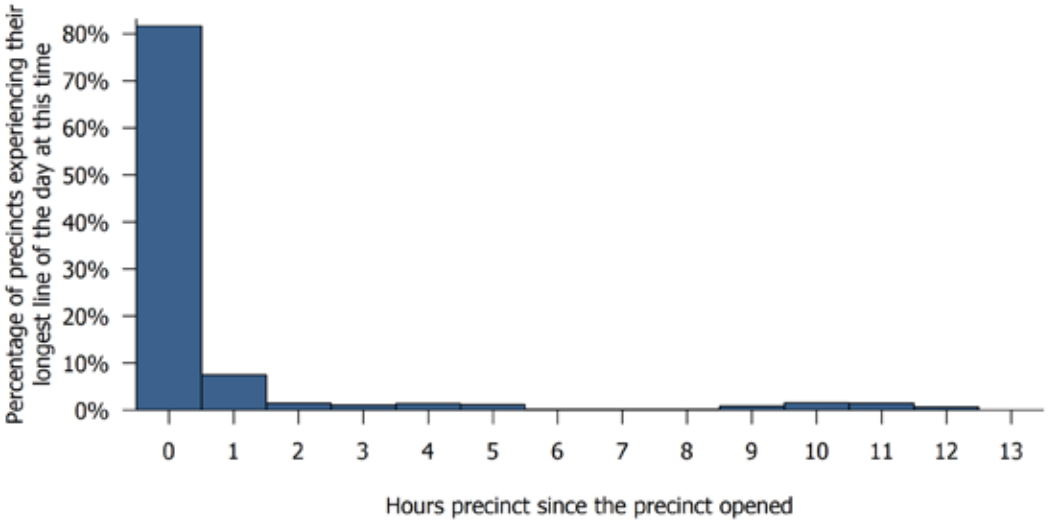
3. The longest lines tended to occur in the morning, right after the polls opened.

On Election Day, America votes in the morning. According to responses to the 2016 Survey of the Performance of American Elections, nearly a quarter of Election Day voters had cast a vote by 9:00 a.m., and 56 percent had voted by noon.

The results from the BPC/MIT study were consistent with this finding. The longest lines tended to be present the moment the polls opened, which was due to the large number of voters who lined up early. Lines during the first couple of hours of voting remained long, even in the best of circumstances, because the large number of voters who arrived before work hours encountered the backlog of voters caused by the opening queue. Other studies have also found this. For instance, the multi-campus academic study mentioned previously found precisely the same thing, although the precincts included in that study came from a different sample of local jurisdictions.[9]

To highlight this point, the graph in Figure 7 presents the hour in which each precinct reported its longest line on Election Day. To account for different precinct opening times in different jurisdictions, the x-axis of the graph displays the number of hours since the precinct opened. (For instance, if the polls opened at 7:00 a.m. and the longest line appeared at that time, the results for the opening hour are reported for Hour 0. If the longest line occurred at 8:00 a.m., the line is reported as occurring at Hour 1.) The y-axis shows the proportion of precincts that experienced their longest line at this time.

Figure 7. When Did Precincts Experience Its Longest Line of the Day? Election Day Sites

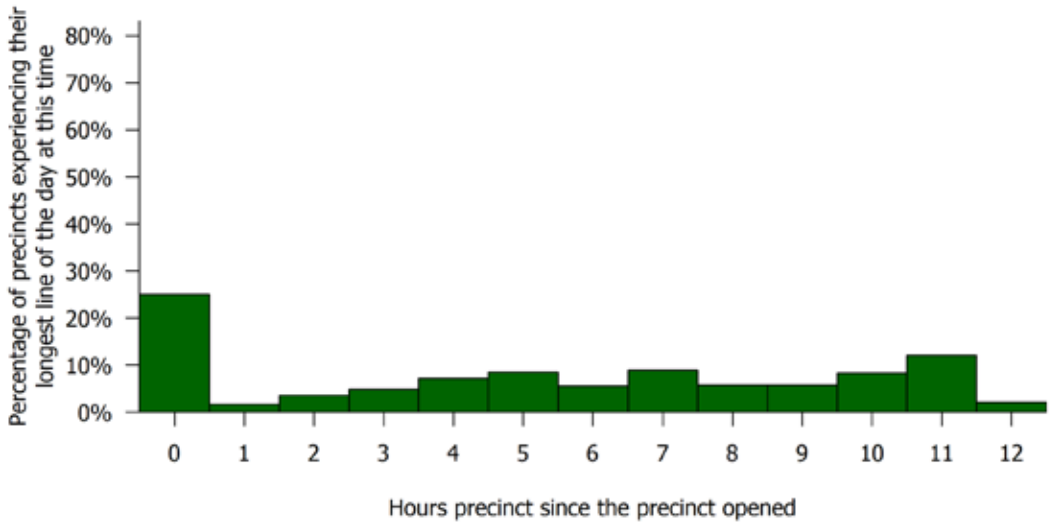


Source: BPC Voting Lines Project

The overwhelming majority of Election Day precincts, 82 percent, had their longest line when the doors opened. An additional 8 percent had their longest lines during the first hour of voting. In other words, 90 percent of Election Day precincts had their longest lines within the first hour of voting, with the lines declining after that.

This pattern is starkly different from that of the early voting sites. (Recall that two of the jurisdictions in the study, Dallas County, Texas, and Wakulla County, Florida, provided information about line lengths during early voting.) The graph in Figure 8 shows the distribution of wait times. While the most common time for an early voting site to experience its longest line was at the beginning of the day, the proportion (25 percent) is substantially lower than the 82 percent in Election Day precincts. As a result, the percentages throughout the rest of the day at early voting sites were considerably higher than at their Election Day counterparts.

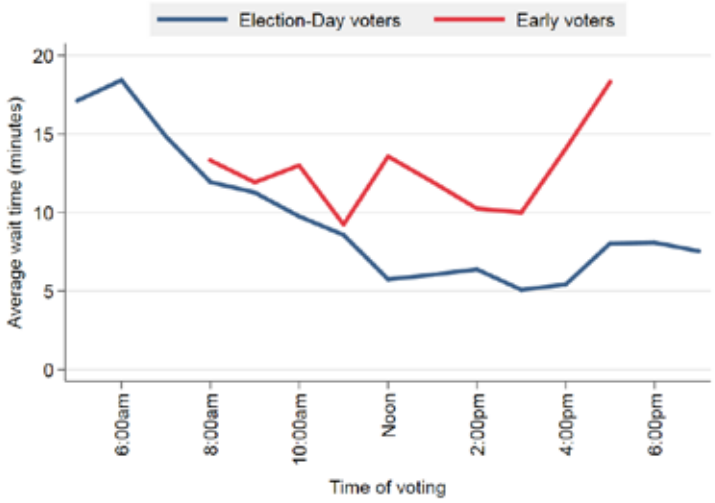
Figure 8. When Did Precincts Experience Its Longest Line of the Day? Early Voting Sites



Source: BPC Voting Lines Project

Although these patterns concerning early voting only come from two counties, and are dominated by the much larger Dallas County, the findings are consistent with other survey research of wait times for voters at different times of the day, depending on whether they voted on Election Day or early. The graph in Figure 9, for instance, shows the average wait times reported by respondents to the 2016 Survey of the Performance of American Elections, based on the time of day they reported voting, for both Election Day voters and early voters. Note that the average reported wait time for Election Day voters was very high at the start of the day, and then fell for the rest of the day. In contrast, the average wait time for early voters was relatively constant throughout the day.

Figure 9. Average Wait Times to Vote in Person, By Hour of the Day

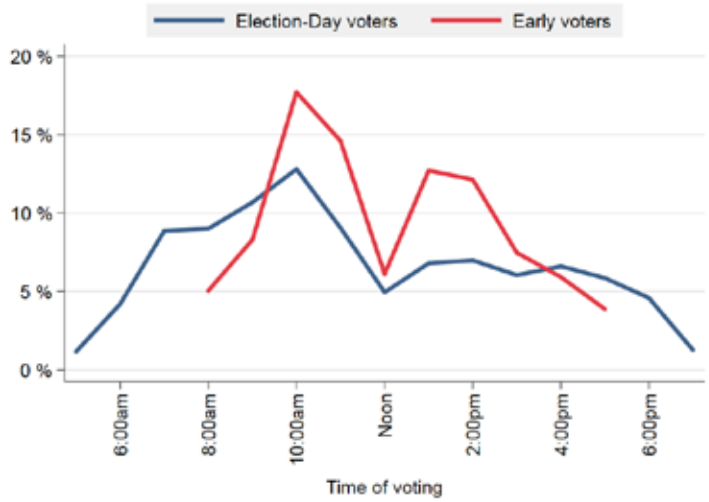


Source: 2016 Survey of the Performance of American Elections

Election Day voters appear to be much more likely to arrive early in the day than in-person voters who rely on early voting. This pattern is illustrated in Figure 10, which shows the distribution of the times of day when voters reported they cast their ballots in 2016, relying on responses to the Survey of the Performance of American Elections. Note, first, that in-person early voting tends to be confined to business hours, whereas Election Day hours begin before work and end in the evening. Thus, the early voting crowd is spread out during the day. Second, notice that arrivals decline during Election Day well before they decline during early voting.

The different arrival patterns of Election Day voters and early voters have important implications for the management of wait times in these different types of in-person voting sites. Managers of Election Day polling sites are helped by the fact that arrivals gradually decline throughout the day, which is a godsend for those polling places that experience an opening-hour rush. Managers of early voting sites have the challenge of having to manage arrival rates that never really drop off. Therefore, if a long line develops early in the day, there is little relief to look forward to as the day wears on.

Figure 10. Percentage of In-Person Votes Who Arrive at The Polls Each Hour of the Day



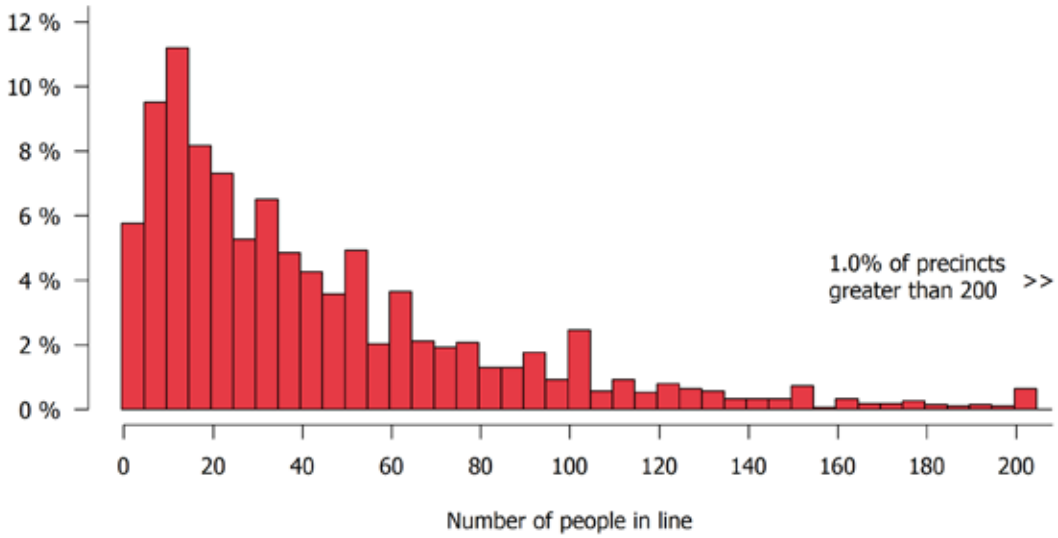
Source: 2016 Survey of the Performance of American Elections

The patterns described here are nationwide averages, and obviously don't apply to every individual county. However, because of the results from this study and others, it is nearly certain that they will apply to most jurisdictions. Still, while the overall pattern of morning voting is strong, and one that jurisdictions across the country should be aware of, the detailed data allows counties to have a good sense of which polling places have the most morning voting, and which go against the trend, so they can allocate resources accordingly.

Fairfax County, Virginia, collected data in 2014 and saw the pattern of morning voting early. Armed with this data, Fairfax was able to dedicate more resources to the start of the day. Fairfax instituted half-day poll-worker shifts so that more poll workers could be present at the busiest time of the day. Not only did Fairfax save money with such a strategy, but it was able to better serve its voters.

The previous analysis shows that the longest lines of the day tend to occur when the polls open. It does not, however, provide information about how many people are actually in those lines. Based on data from Election Day, the average number of people waiting in line at the beginning of the day was 45.3 and the median number was 30. Figure 11 presents the full distribution of these data. Each bar in the graph represents the percentage of Election Day precincts that had people already in line when the polls opened. Approximately 10 percent of precincts had opening lines of more than 100 people; 35 percent had fewer than 20 waiting to cast a ballot. Only 1 percent of the precincts reported zero people in line when the polls opened.

Figure 11. Distribution of The Number of People in Line When Precincts Opened On Election Day

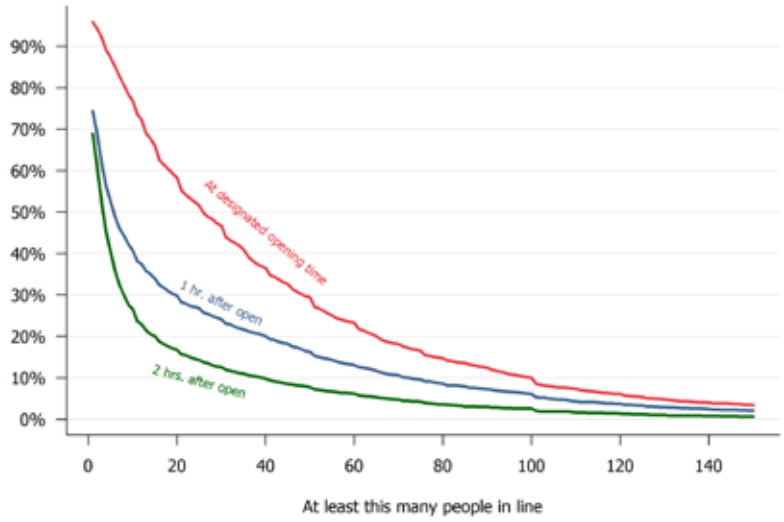


Source: BPC Voting Lines Project

4. Although lines tend to be the longest at the beginning of the day, they dissipate quickly in most precincts.

Although lines tend to be the longest at the beginning of the day, most precincts managed to reduce the length of their lines quickly. Figure 12 shows a percentage of the Election Day precincts in which the line at hours 0, 1, or 2 was of a certain length. The percentage of precincts with any given line length decreased with each passing hour. For example, 10 percent of precincts had more than 100 people in line when they opened, but within one hour, that number had dropped to 6 percent, falling to 3 percent within two hours. Similarly, while only about a quarter (23 percent) of precincts had fewer than 10 people in line at the beginning, three-quarters (73 percent) had lines shorter than 10 within two hours.

Figure 12. Percentage of Precincts with at Least a Certain Number of People in Line Early in the Day

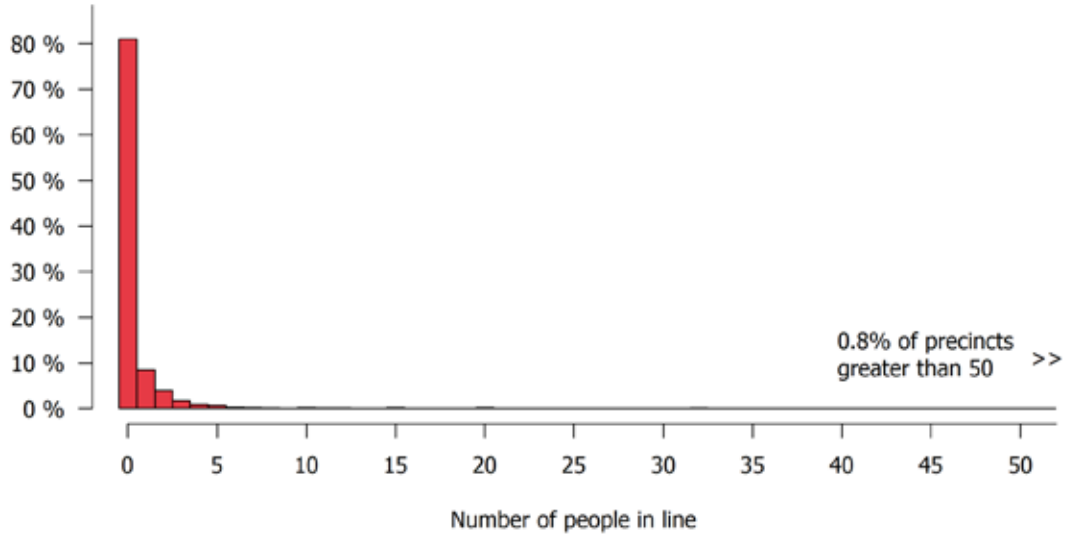


Source: BPC Voting Lines Project

5. Long lines at the end of the day are rare.

By the end of the day, the dynamics of line length have almost completely reversed. As Figure 13 shows, almost every precinct (81 percent) had zero people in line at the time they were supposed to close at the end of the day. Another 9 percent had just one person waiting to be checked in. In total, only 2 percent of precincts reported at least 10 people waiting to check in when they were supposed to close.

Figure 13. Distribution of The Number of People in Line When Precincts Closed On Election



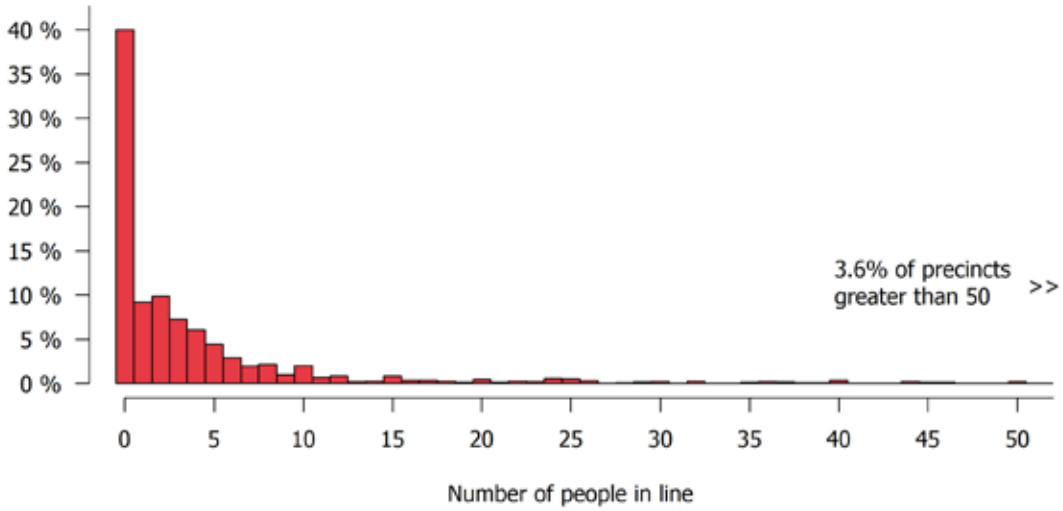
Source: BPC Voting Lines Project

Further investigation of the data provides evidence that the short lines at the end of the day result from a drop-off in the arrival rates as Election Day progresses.

6. Lines in most precincts are relatively short at noon and at 5:00 p.m.

Despite common concerns about voters rushing to the polls during lunchtime and after work, in most precincts the lines tended to be fairly short at these times. Figure 14 shows the distribution of line lengths at all Election Day precincts at noon. At noon, 40 percent of precincts had nobody in line, and 85 percent had fewer than 10 people waiting to check in. Similarly, at 6:00 p.m., 37 percent of polling places had nobody waiting in line, and 84 percent had fewer than 10 waiting.[10]

Figure 14. Distribution of The Number of People in Line at Noon On Election Day



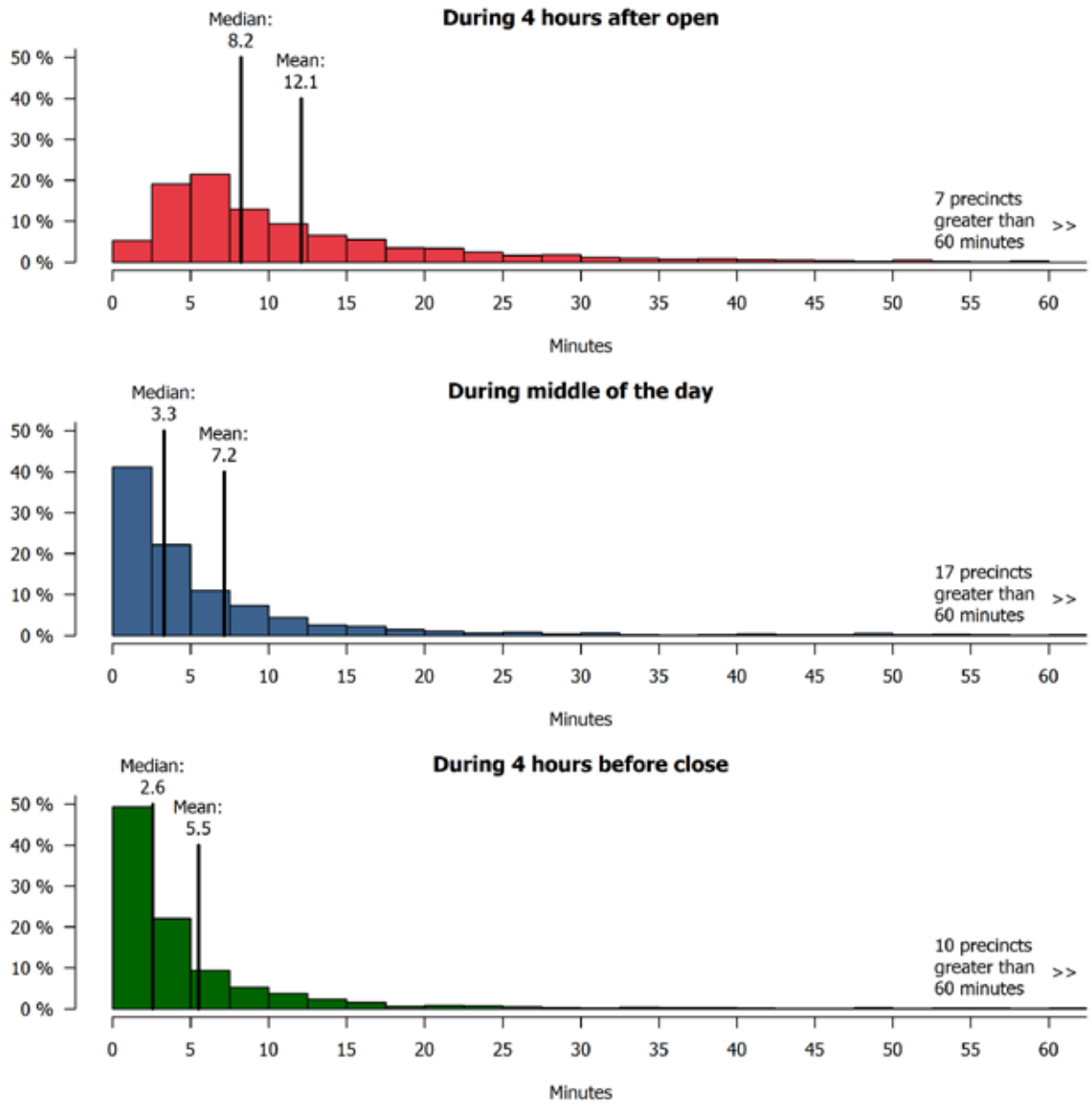
Source: BPC Voting Lines Project

7. The longest wait times occur in the morning. They decline on average throughout Election Day.

Given the results reported thus far, it should not be surprising that average wait times on Election Day tended to drop as the day progressed. Researchers were able to calculate average wait times using Little's Law for the counties that provided hourly check-in data. To explore average wait times during different times of the day, they divided Election Day into three time periods: the four-hour window at the beginning of the day; the four-hour window at the end of the day; and the midday window, which lasted either four or five hours depending on how long the precinct was supposed to be open. Average morning, mid-day, and evening wait times in each precinct were found using Little's Law.

The graphs in Figure 15 display the distribution of wait times across polling places during each of the time windows. Just as the morning had the most people standing in line, so too did it have the longest average wait times. On average, voters who arrived between the precinct's opening time and four hours later waited approximately 12 minutes to vote. Just 5 percent of precincts had waits between zero and 2.5 minutes, and the modal precinct had an average wait in the morning of between 5 and 7.5 minutes.

Figure 15. Average Wait Times at Various Points of the Day



Source: BPC Voting Lines Project

Later in the day, wait times shrank as the number of people in line diminished faster than arrival rates declined. During midday, the average wait time was nearly cut in half to 7.2 minutes. More than half of precincts (63 percent) had a wait of less than five minutes, and 41 percent of precincts had average waits of between zero and 2.5 minutes.

At the end of the day, in the four hours before closing time, lines tended to get even shorter. The average precinct had a wait time of 5.5 minutes, and almost half the polling places had average waits in the lowest category of zero to 2.5 minutes.

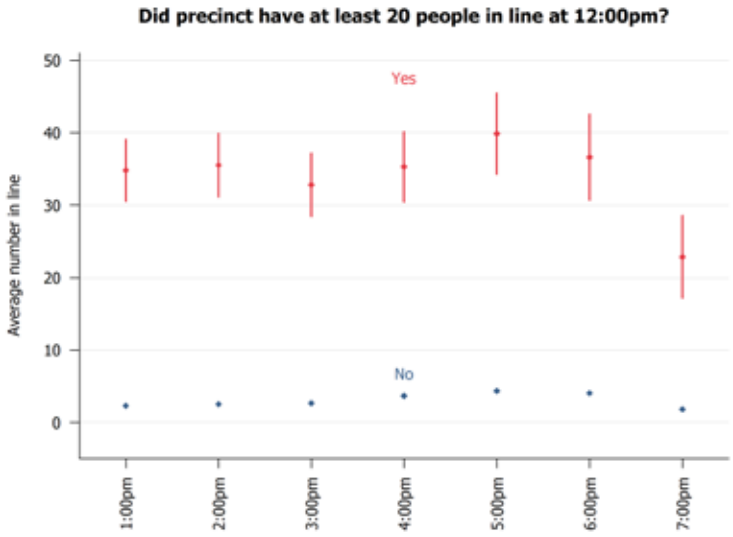
8. If a precinct clears its morning line quickly, it is unlikely to experience long wait times for the rest of the day. If the morning line persists, long wait times are likely to occur for the entire day.

There is a crush of morning voting on Election Day. The BPC/MIT study shows the importance of clearing that morning line. A high volume of voters at the start of the day will often lead to lines at most precincts. However, most of those precincts showed the ability to clear those lines within the first couple of hours of voting, never to experience them again for the rest of the day. Conversely, the precincts that could not clear their morning lines were highly likely to see long lines, and long waits, until they closed their doors, often hours after the official poll-closing time.

Does having a long line right now mean that a precinct is likely to have one in two or six hours? Do short lines early in the day make a precinct more likely to be burdened by heavy arrivals of voters after 5:00 p.m.? Overall, the data suggest that the answers to these questions are yes to the first and no to the second. With the exception of the first hour or so that a precinct is open, having a long line at any given moment is a strong predictor of having a long line throughout the rest of the day.

The graph in Figure 16 illustrates this point. The graph presents the average number of people in line at each hour between 1:00 p.m. and 7:00 p.m. The red dots and 95 percent confidence intervals represent precincts in which there were at least 20 people in line at noon. The blue dots and confidence intervals reflect precincts where there were 19 people or fewer in line at noon. As you can see, having a modestly long line at noon is a very good predictor of how long the lines will be throughout the rest of the day. Precincts with very few people in line at lunchtime tended to have lines in the single digits throughout the rest of the day. Precincts with 20 or more in line at lunchtime tended to have several dozen in line during the afternoon and evening.

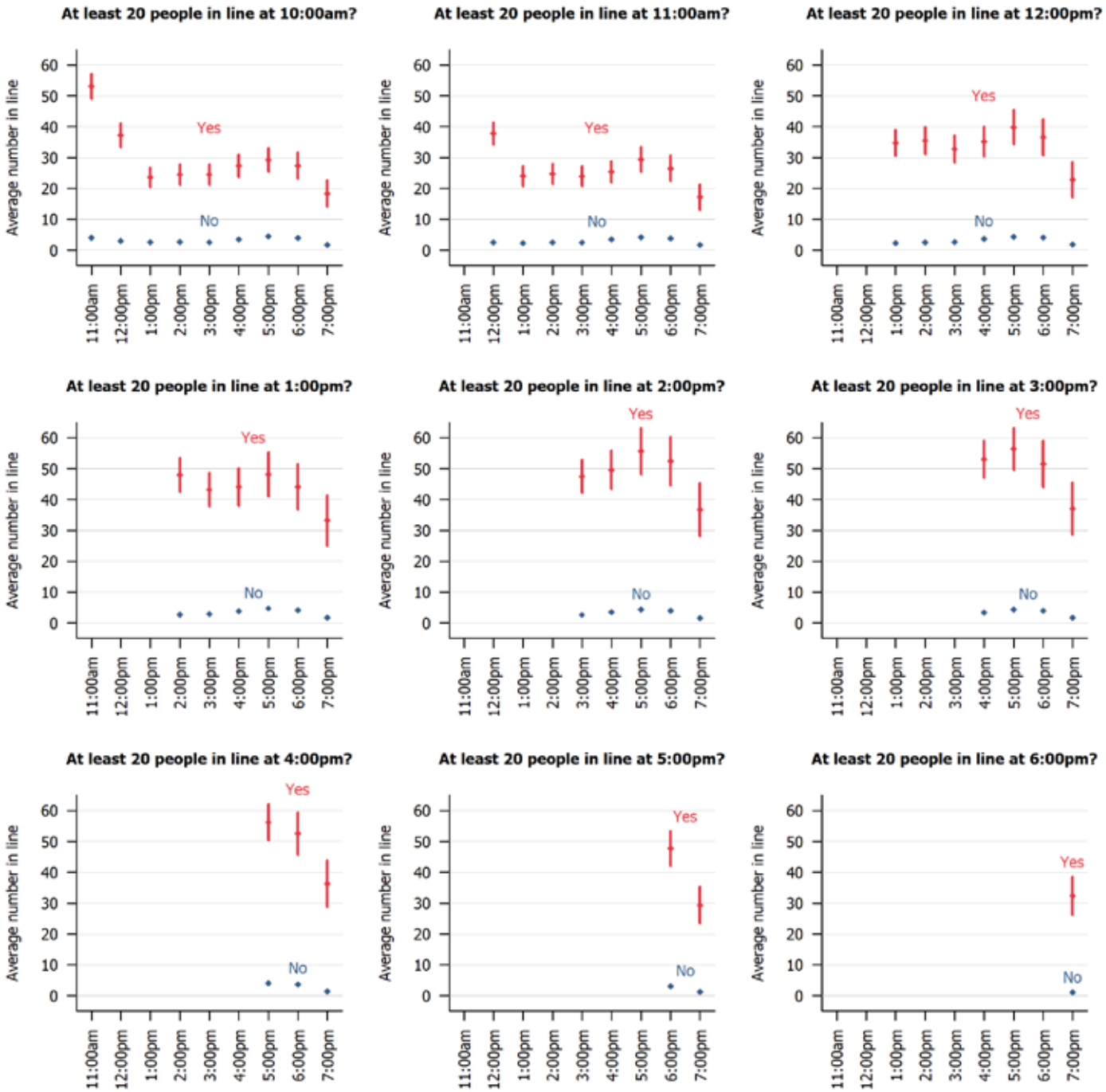
Figure 16. How Well Does a Long Line at Noon Predict Long Lines for the Rest of the Day?



Source: BPC Voting Lines Project

This pattern was not unique to the noon hour. Figure 17 emulates the noon results shown above for every hour between 10:00 a.m. and 6:00 p.m. At every hour, whether or not a precinct had at least 20 people in line is strongly predictive of the average line length through the remainder of the day. If, for example, a precinct had at least 20 people in line at 10:00 a.m., one would expect there to be roughly 27 people in line eight hours later at 6:00 p.m. On the other hand, if the precinct had fewer than 20 people in line at 10:00 a.m., there would likely only be four people in line at 6:00 p.m.

Figure 17. How Well Do Long Lines Now Predict Long Lines for The Rest of the Day?



Source: BPC Voting Lines Project

For local election officials, the results in this section could be put into action to deal with lines on Election Day in a couple of ways. First, the pattern of long lines in the morning can serve as an early warning device that lines might grow out of control during the day. Of course, a long line during the first hour of voting is common, even in polling places that clear out by 9:00 a.m. But, if a polling place still has a long line after two hours of voting, it is a sign that some extraordinary action needs to be taken, such as bringing in an extra poll book or poll workers.

In thinking about planning ahead, if a set of precincts in a county are regularly afflicted with long lines throughout the morning, then it might be appropriate to add additional staff resources during the morning rush. In some states, poll workers are required to work the entire day; thus, putting in extra staff to handle the morning rush may be impossible. (However, changing the law to allow part-day poll workers may also be a good thing.) But in a state where partial-day poll workers are already allowed, adding another cadre of half-day workers to the morning hours may very well pay off.

Conclusion: What Isn't Counted Can't Be Managed

Before Obama issued the call to fix the problem of long election lines, not much was known about why lines formed at some polling places and not at others. We now know that long lines most fundamentally form when there is a misallocation of resources necessary to handle the service requirement of a polling place. In other words, there aren't enough poll books or voting booths or ballots or machines to handle the crowd.

The PCEA unleashed a flurry of activity among academics and public-minded institutions to help the election administration community adapt the tools of modern line management to polling places. One thing is clear about these management tools: They require election administrators to know how long lines are at their polling places, to know when their voters arrive at the polling places, and to know how they have distributed resources to their polling places.

★ ★ ★

"Management tools require election administrators to know how long lines are at their polling places, to know when their voters arrive at the polling places, and to know how they have distributed resources to their polling places."

If these things aren't measured, then polling place lines can't be managed with any certainty. The most complicated thing to measure is how many people are waiting in line. However, the BPC/MIT line-length project demonstrates that measuring lines is not hard at all. And, with that knowledge, comes the ability to provide voters with a more confidence-inspiring experience at the polls.

Call to Election Administrators: Join The BPC/MIT Line Program

BPC and MIT believe that measuring lines at every hour at every polling place should be a universal practice of election officials. We are expanding our program in 2018 and we encourage election officials from large and small jurisdictions across the country to join our program.

If you are interested in participating, we ask that your county assign a poll worker at each polling place to count the number of people in line at every hour and record it on a paper sheet. We will input the data and provide you with individualized analysis of daily average line waits and arrival rates at each polling place. There is no cost to local election officials for this program.

For more information or to contact us to join the program, please visit: www.bipartisanpolicy.org/votinglines.

Want to Know More?

The principles behind the BPC/MIT line-length program have been a core part of management science for decades. The following is a brief list of resources that may be especially helpful to election administrators.

- Alexander S. Belenky and Richard C. Larson, "To Queue or Not to Queue?," *OR/MS Today*, 2006. Available at: http://www.orms-today.org/orms-6-06/queues.html. (Brief, accessible introduction to queuing theory as applied to elections.)
- Caltech/MIT Voting Technology Project, "VTP Toolkit." Available at: http://web.mit.edu/vtp/. (Collection of online tools that help with allocating resources and minimizing polling place lines.)
- Charles Stewart III, *Managing Polling Place Resources*, Caltech/MIT Voting Technology Project Report, 2015. Available at: http://web.mit.edu/vtp/Managing%20Polling%20Place%20Resources.pdf. (Comprehensive report on polling place lines and how to manage and study them.)
- Charles Stewart III and Stephen Ansolabehere, "Waiting to Vote," *Election Law Journal* 14, no. 1 (2015): 47-53. (Overview of research presented to the Presidential Commission on Election Administration about lines at polling places.)
- Richard C. Larson and Amedeo R. Odoni, *Urban Operations Research* (Upper Saddle River, NJ: Prentice-Hall, 1981). Available at: http://web.mit.edu/urban_or_book/www/book/. (Chapter 4 provides a straightforward introduction to queuing theory.)

Appendix A: Participating Jurisdictions

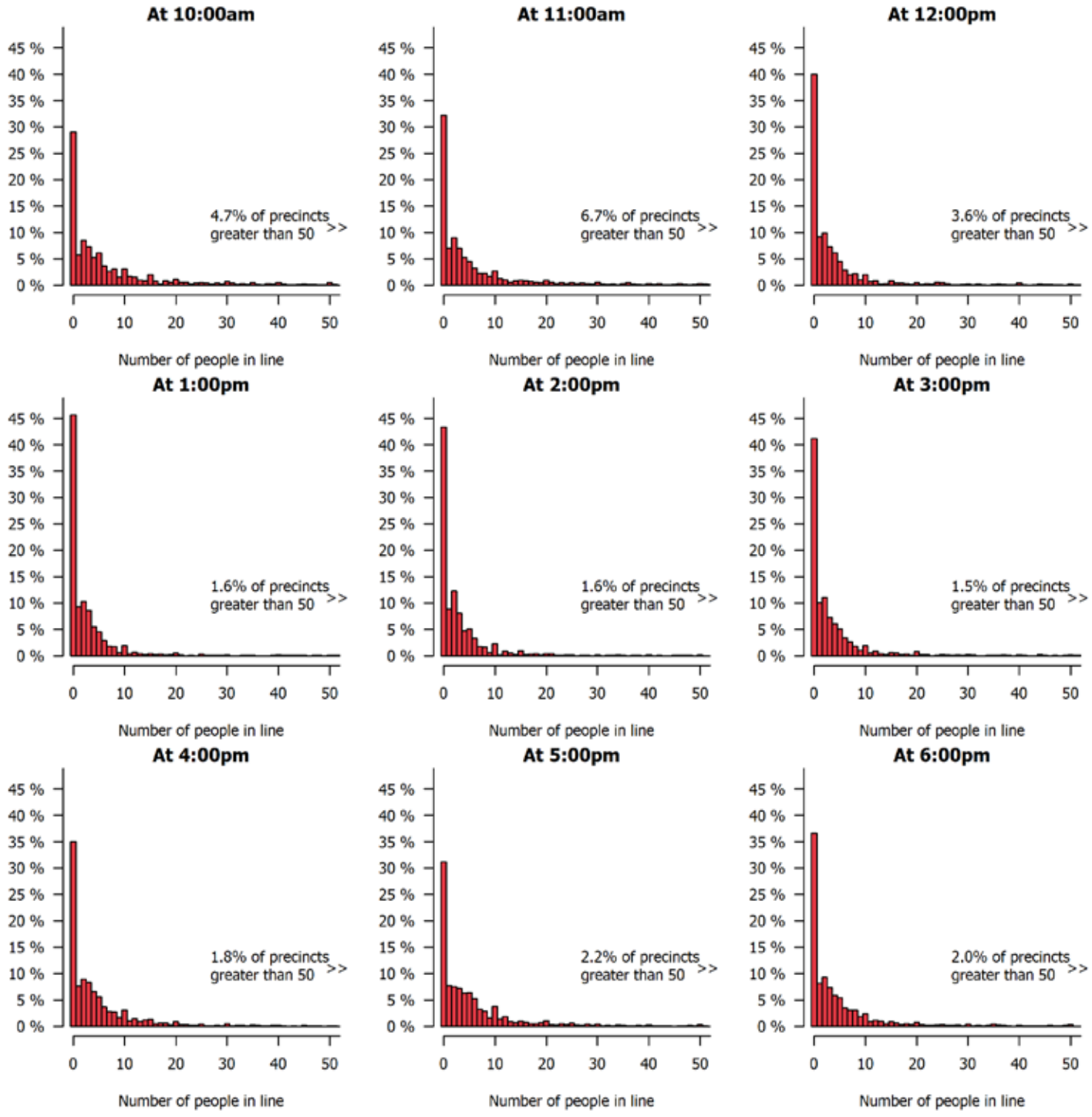
Jurisdiction	Precincts	Hourly Observations
Pinal County, AZ	72	885
San Diego County, CA	642	7,380
Arapahoe County, CO	19	237
Clay County, FL	37	473
Escambia County, FL	67	863
Hernando County, FL	31	389
Lake County, FL	84	1,087
Levy County, FL	10	130
Martin County, FL	15	185
Nassau County, FL	13	169
Osceola County, FL	38	487
Saint Johns County, FL	37	481
Saint Lucie County, FL	49	643
Seminole County, FL	8	103
Taylor County, FL	1	13
Wakulla County, FL	13	299
Cook County, IL	1,468	17,499
Alger County, MI	1	13
Allegan County, MI	4	55
Alpena County, MI	5	70
Antrim County, MI	1	14
Barry County, MI	1	14
Bay County, MI	1	14

Jurisdiction	Precincts	Hourly Observations
Berrien County, MI	3	41
Calhoun County, MI	4	54
Charlevoix County, MI	2	27
Cheboygan County, MI	1	14
Clare County, MI	4	56
Clinton County, MI	9	123
Dickinson County, MI	3	41
Eaton County, MI	16	207
Genesee County, MI	9	123
Gladwin County, MI	1	14
Gogebic County, MI	1	14
Gratiot County, MI	2	28
Huron County, MI	1	14
Ingham County, MI	1	14
Ionia County, MI	3	40
Iosco County, MI	1	14
Jackson County, MI	5	64
Kalamazoo County, MI	26	338
Kent County, MI	67	868
Lapeer County, MI	7	91
Lenawee County, MI	1	14
Livingston County, MI	6	83
Macomb County, MI	62	794

Jurisdiction	Precincts	Hourly Observations
Manistee County, MI	3	42
Marquette County, MI	4	56
Mecosta County, MI	3	42
Midland County, MI	3	41
Missaukee County, MI	8	105
Monroe County, MI	14	191
Muskegon County, MI	4	52
Oakland County, MI	126	1,621
Oceana County, MI	2	28
Ogemaw County, MI	1	14
Oscoda County, MI	1	14
Otsego County, MI	1	13
Ottawa County, MI	5	68
Presque Isle County, MI	1	14
Saginaw County, MI	6	84
Saint Clair County, MI	14	179
Tuscola County, MI	2	27
Van Buren County, MI	5	69
Washtenaw County, MI	64	740
Wayne County, MI	36	475
Wexford County, MI	3	42
Hennepin County, MN	114	1,454

Jurisdiction	Precincts	Hourly Observations
Platte County, NE	29	369
Hamilton County, OH	252	3,186
Collin County, TX	70	861
Dallas County, TX	45	4,968
Chesapeake City, VA	54	687
Chesterfield County, VA	50	635
Clarke County, VA	7	85
Fairfax City, VA	5	67
Fairfax County, VA	218	2,849
Falls Church City, VA	2	19
Fauquier County, VA	19	236
Goochland County, VA	9	118
Hanover County, VA	36	490
Isle Of Wight County, VA	14	194
Loudoun County, VA	28	318
Manassas City, VA	3	34
Petersburg City, VA	5	70
Prince William County, VA	70	909
Stafford County, VA	27	313
Williamsburg City, VA	2	28
York County, VA	12	167
Total	**4,229**	**56,553**

Appendix B: Voting Lines at Various Times During Election Day



Source: BPC Voting Lines Project

Endnotes

1 Charles Stewart III and Stephen Ansolabehere. "Waiting to Vote." *Election Law Journal* 14, no. 1 (2015): 47-53.

2 Caltech/MIT Voting Technology Project, *Voting: What Is/What Could Be*, July 2001. Available at: http://vote.caltech.edu/reports/1.

3 Robert Stein, et al., "Waiting to Vote in the 2016 Presidential Election: Evidence from a Multi-Campus Study," paper presented at the Election Science, Reform, and Administration summer conference, Portland, Oregon, July 27-28, 2017.

4 This report is about managing lines and wait times during in-person voting. Most in-person voting occurs on Election Day, although an increasing amount of in-person voting now occurs during early voting periods in most states. For the sake of simplicity, when this paper refers to voting on Election Day, the same principles and techniques also apply to in-person voting during early voting periods.

5 The *Managing Polling Place Resources* report can be downloaded from the VTP website, or directly from the following URL: http://web.mit.edu/vtp/Managing%20Polling%20Place%20Resources.pdf.

6 This calculation is based on a nationwide turnout level of 138,846,571, reported by the United States Elections Project. Available at: http://www.electproject.org/.

7 Charles Stewart III and Stephen Ansolabehere. "Waiting to Vote." *Election Law Journal* 14, no. 1 (2015): 47-53.

8 Line lengths were only observed at the times that poll workers recorded them, which, at almost all jurisdictions, occurred at the top of every hour. It is possible that a precinct may never have experienced a line of 10 people at the top of any hour but did experience one at the bottom of an hour. This would mean that the estimate of one-third here is slightly inflated. Given the strong across-time correlations of line length within a precinct, however, the true percentage is probably not too much lower than one-third.

9 Robert Stein, et al., "Waiting to Vote in the 2016 Presidential Election: Evidence from a Multi-Campus Study," paper presented at the Election Science, Reform, and Administration summer conference, Portland, Oregon, July 27-28, 2017.

10 See Appendix B for the distribution for all hours between 10:00 a.m. and 6:00 p.m.

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