Why Computer DRE Voting Machines Cause Long Lines—Why Paper Ballot/Optical Scan Can Prevent Lines

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I am a resident of Baltimore City and have served as an election judge for Ward 9, precinct 5 at Mervo School in the two most recent elections. I am a physicist and a Professor of Radiology at Johns Hopkins Medical School.

Following the Help America Vote Act of 2002, computerized touch screen Direct Recording Electronic (DRE) voting machines have been used in many states. A significant and perhaps underappreciated problem that has become increasingly apparent is that these machines cause the formation of long lines at polling places. These lines have in some cases made people wait hours to vote, and disenfranchised those who have had to leave without voting.

This has happened in many places—Maryland, California, Florida, Mississippi, Ohio, Pennsylvania, Tennessee, Utah and elsewhere [1-10]. The obvious reason is that there were too many people voting on too few machines. What is not so obvious is how many DREs would be enough. I have studied this question and have worked out a “Queue Stop” rule that will eliminate lines (see Appendix) for specific voting conditions. Unfortunately, nobody can afford enough DREs to follow this rule.

Once an election has started, it is not possible to increase the number of DREs, even if it becomes apparent that a large number of voters or a long ballot is creating long lines.

In contrast, paper ballot systems make it easy and inexpensive to keep the voting process moving efficiently. With paper ballot systems, marking booths where voters mark their ballots are the equivalent traffic choke point to DREs. These marking booths might be a purpose-built table with a screen, or simply a piece of cardboard placed on or taped to a table to form a screen, such as we use in Maryland for provisional ballots.

The formation of lines depends on the interplay among number of voters, number of machines and the time needed for each person to vote. It is a process similar to what everyone experiences on roads, as people who live around Baltimore and Washington know only too well. Traffic flows smoothly as long as the density is low. As volume increases, traffic gradually slows until, at some density, it locks up and cars accumulate into long lines which can take hours to clear.

Ms. Rebecca Wilson has told you about waits of over two hours at the Prince George’s County polling place where she works as a chief election judge.

This phenomenon is described by the mathematics of queuing theory, which I have used to study voter flow [11]. Figure 1 shows a series of curves illustrating how sensitive the formation of lines is to the factors I mentioned above. Unexpected fluctuations—extra people in the morning or evening, a long ballot—can suddenly cause multi-hour voter waits. The process is very nonlinear, i.e., small changes can have big consequences.

Figure 1 is based on a polling place with 10 DREs and 150 actual voters per DRE. This would be the situation for a typical Maryland polling place with a 75% turnout, as Maryland law says that there must be one DRE for every 200 registered voters [12]. If we look, for example, at the curve marked > 60 minutes, we see that waits of more than an hour would occur in 0.1% of precincts where it takes an average of 4.6 minutes to vote, 1% of precincts where it takes 4.8 minutes to vote and 10% of precincts where it takes 5 minutes to vote.

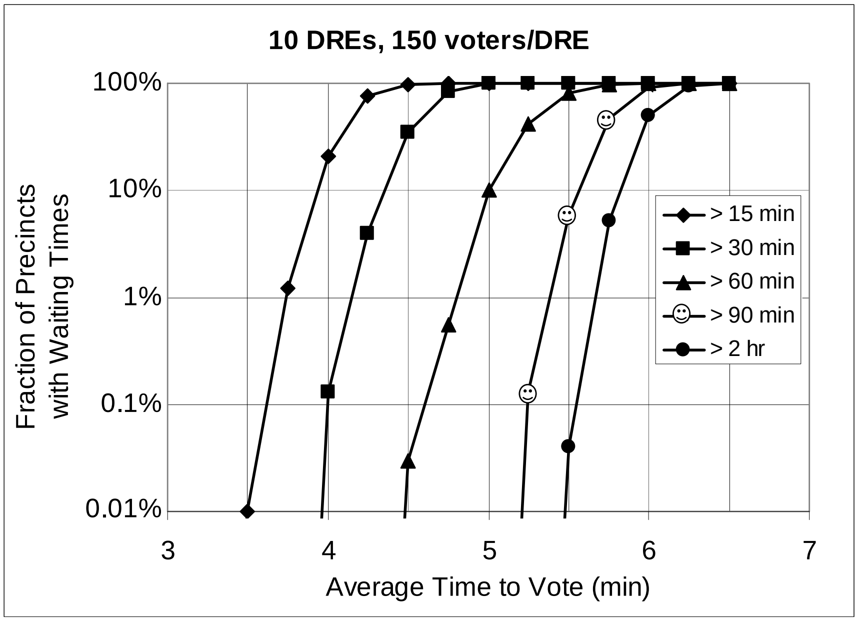

Figure 1. Fraction of precincts with long waits vs. average time to vote. The calculation is based on a precinct with 10 DREs and 1500 actual voters. For example, there will be waits of over an hour for 0.1% of precincts where voting takes 4.6 minutes, 1% for 4.8 minutes and 10% for 5 minutes. Thus small variations in voter numbers or voting times can cause big changes in waiting times.

Elections are critical to our democracy and cannot tolerate malfunction, including long delays to vote. It is not good enough to have 90% or 99% or even 99.9% of elections working. Maryland has nearly 1800 polling places. Would it be OK to have 180 polling places (10%) or 18 polling places (1%) or even 2 (0.1%) seriously messed up? I don’t think so.

In order to avoid lines, then, it is necessary to have a very large reserve capacity. The Maryland formula for numbers of DREs seems reasonable. However, if you get a 75% turnout and it takes 5 minutes or more to vote, then there will be a significant number of polling places with people waiting more than an hour.

In contrast, paper ballot systems are scalable and can be quickly and inexpensively configured to meet a wide range of unforeseen contingencies. New Hampshire keeps a reserve stack of cardboard privacy screens at each polling place if long lines start to form.

Long waits are not just inconvenient; they undermine democracy, because a lot of people—the elderly, people with disabilities or illnesses, people who have to get back to work, people who have to take care of children—cannot hang around indefinitely and may leave without voting, thereby becoming disenfranchised [4]. Everyone should be able to vote in a timely and efficient manner. This will not universally happen with DREs, but it can be done with paper ballots.

Appendix—The “Queue Stop” rule

The “Queue Stop” rule (a result of Queuing Theory calculations [11]) works as follows. Suppose you have a 13 hour (780 minute) Election Day, and it takes 3 minutes to vote. Then the maximum number of voters per machine is found by dividing the total time by the minutes to vote, and then divide again by two. So (780/3) ÷2 = 130. If you have significantly more than 130 voters per machine, there will likely be long waits somewhere.

The formula can also be used to determine the maximum average voting time. Suppose you have a 780 minute Election Day and 150 voters. To find what the average voting time should be, divide the total time by the number of voters, and then divide again by 2. So (780/150) ÷2 = 2.6 minutes. Longer voting time will probably produce long lines at some polling places.

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