User Guide: Accessible Voting Machines Calculator

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Introduction

The Help America Vote Act (HAVA) established the right for the more than 40 million Americans with disabilities (making up roughly one-sixth of the total electorate) to mark, cast, and verify their ballots privately and independently.1 HAVA requires a minimum of one accessible voting machine per voting location. To help avoid long lines, a voting location may need more than one accessible voting machine. Americans with disabilities are a growing demographic that varies in size but makes up, on average, 16 percent of the total population of American counties and includes those with mobility, visual, communicative, physical, or cognitive impairments. There may be additional voters who benefit from using accessible voting machines, including language-minority communities and elderly voters. The U.S. Election Assistance Commission partnered with the University of Rhode Island's Engineering for Democracy Institute to create a calculator to help election officials and policymakers determine how many accessible voting machines should be deployed to voting locations to achieve minimal wait times.

The Accessible Voting Machines Calculator provides recommendations on the number of accessible voting machines necessary to minimize voter wait times at a particular voting location. Users may enter voting location information and approximate quantities of existing voting equipment to estimate voter wait times, visualize the impact of adding additional accessible voting machines, and determine the recommended number of accessible voting machines to minimize wait times.

The layout of the Accessible Voting Machines Calculator consists of a left panel and a right panel. The left panel contains menus, settings, and options users may adjust to represent a particular voting location. The right panel contains the outputs of the calculator, including estimated wait times, a wait time plot, and optimization results. This walkthrough provides additional information about the voting processes included in this calculator and the components of the left and right panels. It also provides instructions for effectively using the calculator. A step-by-step example can be found on page 4.

[1] See: Schur, L. & Kruse, D, 2024. Projecting the Number of Eligible Voters with Disabilities in the November 2024 Elections. Rutgers-New Brunswick, Program for Disability research.

Methodology

The results presented by this calculator are generated through a combination of simulation models and algorithms to predict voter wait times based on entered voting location information and resource allocations. Processing times for each voting process are based on real election data collected between 2018 and 2024.

The simulation models used in this calculator take advantage of real election data and your inputs to represent a voting process. The variability and randomness expected in real voting processes are reflected in this simulation to create accurate voter wait time estimates. While the calculator is running, virtual voters are arriving to a voting location, waiting for processes to become available, and completing each step of the voting process. Due to the application of simulation in this calculator, slightly different results may appear when running the simulation multiple times with the same inputs. However, these differences will be marginal.

To model a real voting process using simulation, we must simplify the voting process by making certain assumptions due to the limitations of computing and the complexity of the real world. The core assumptions about the voting process that we make in this calculator that may differ from some real voting locations are:

- The voting location is open for 13 hours,
- Voters with disabilities will only mark their ballots at accessible voting equipment,
- Voters without disabilities will only mark their ballots at non-accessible voting equipment (e.g., hand marking at voting booths or ballot marking devices that are not accessible) unless only accessible equipment is offered,
- Voters with disabilities take between 6% and 32.5% longer to mark their ballot than voters without disabilities,[2]
- Voters will not leave the voting location without successfully voting (e.g., voters will not leave if they are waiting too long), and
- Provisional voting or other exceptional circumstances are not present in the voting location.

While one or more of these assumptions may not align with the voting process in your location, the estimated wait times are still broadly applicable to your location and can assist in making accessible voting machine allocation decisions.

The recommended number of accessible voting machines are determined through an optimization algorithm to achieve wait times under the desired duration set by the user. It may take several minutes for results to be generated, especially in

[2] See: Lee, M.S., Lyoo, C.H., Lee, M.J., Sim, J., Cho, H., Choi, Y.H., 2010. Impaired finger dexterity in patients with Parkinson's disease correlates with discriminative cutaneous sensory dysfunction. Movement Disorders 25. URL: https://doi.org/10.1002/mds.23304.

cases where a large number is entered into the Voting Location Number of In-Person Voters input.

In combination, these methods allow you to enter information about a voting location and your voter population to estimate the recommended number of Accessible Voting Machines to ensure wait times are manageable for both voters with and without disabilities.

Definitions

Accessible Voting Machines – Electronic devices that facilitate ballot marking, offering accessibility features such as audio ballots, accessible keypads with Braille text, and high contrast screen options.

Ballot Boxes/Scanners – Electronic devices or ballot boxes in which a voter inserts their ballot to cast their vote.

Check-in Stations – Electronic poll books or paper poll books where poll workers check voters into the voting location, allowing them to receive and mark a ballot.

Hand-marked Ballot Voting Station – A station where paper ballots may be hand-marked by voters, such as plastic or cardboard privacy screens or tables. One privacy booth is equal to a single station where a voter hand marks their ballot.

Total Wait Time – The average time that voters spend waiting for parts of the process to become available throughout the entire voting process.

Voter Arrival Pattern – The rate at which voters arrive to a voting location at each hour of a voting day.

Voting Age Population with Disabilities (Percentage) – The percentage of voting age individuals with disabilities, at the jurisdiction level, according to the American Community Survey.

Voting Day – A 13-hour period in which voting locations are open and processing voters.

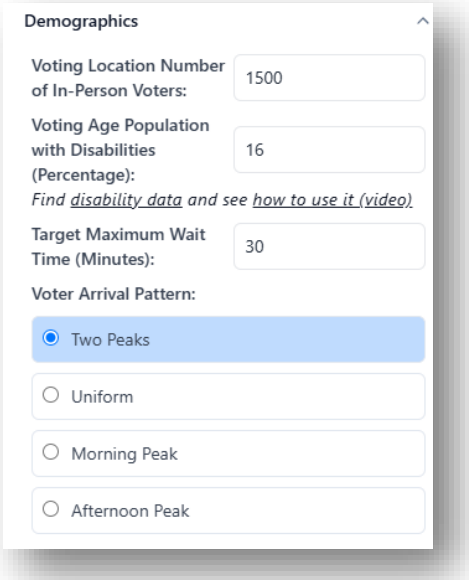
Voting Location Number of In-Person Voters – The number of voters expected to vote at a voting location during a single 13-hour voting day.

Voting Machines (non-accessible) – Electronic devices enabling voters to mark ballots through a touch screen interface that do not offer accessibility features (see Accessible Voting Machines).

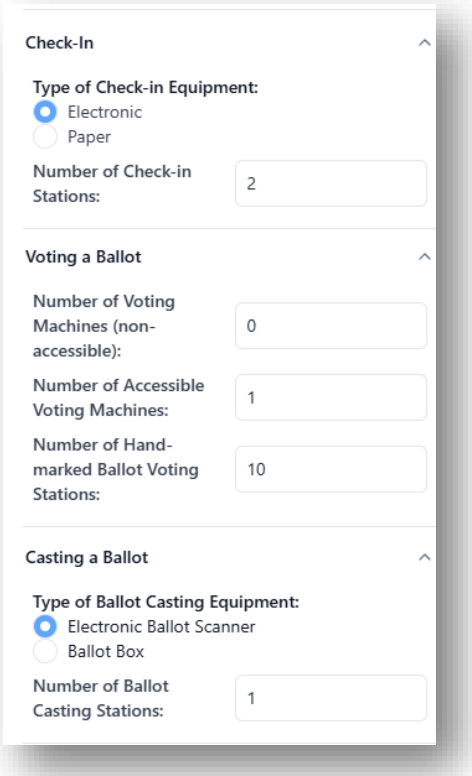
Wait Times - The average time that voters spend waiting for a particular part of the process to become available – check-in, voting a ballot, or casting a ballot.

Step-by-Step Example

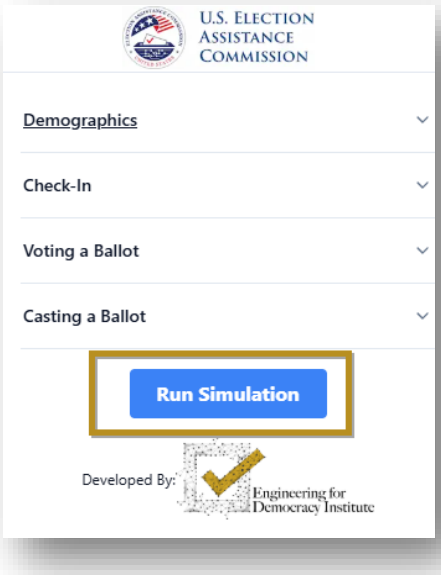
1. In the *Demographics* menu on the **left panel**:
    1. Set the Voting Location Number of In-Person Voters to 1500,
    2. Set the Voting Age Population with Disabilities (Percentage) to 16,
    3. Set the Target Maximum Wait Time in Minutes to 30,
    4. And set the Voter Arrival Pattern to Two Peaks.



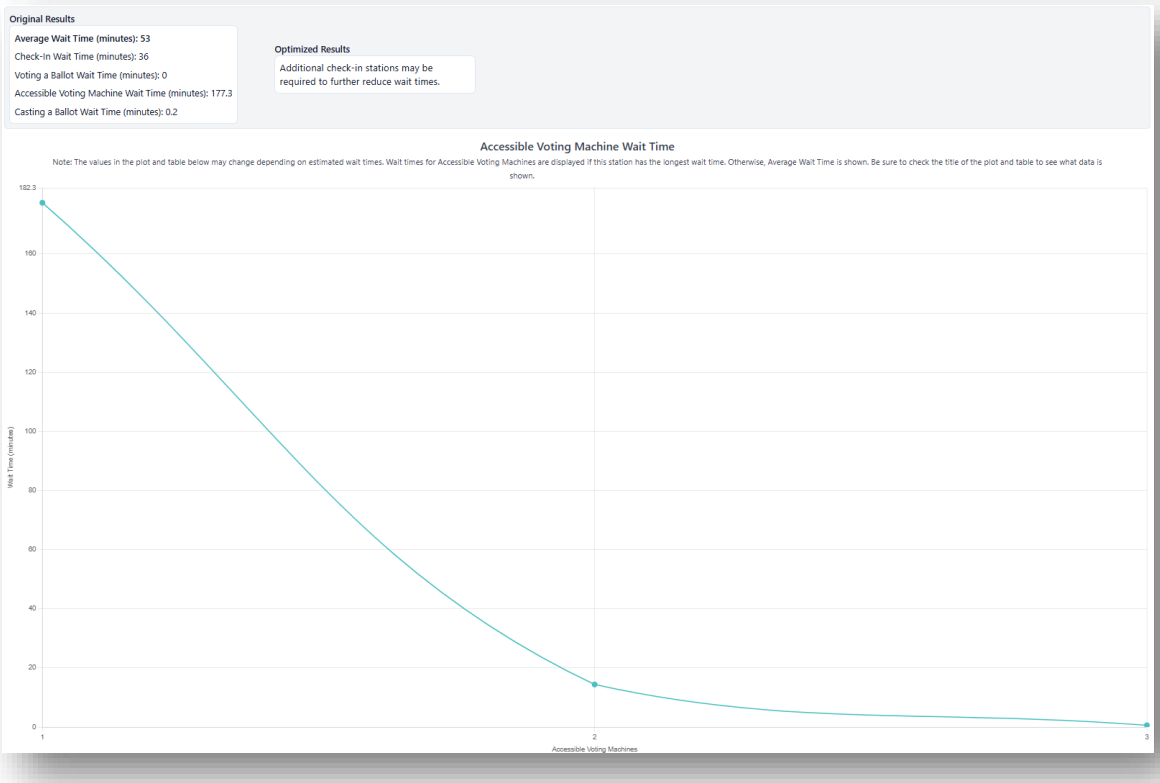
2. Locate the voting process tabs (i.e., *Check-In*, *Voting a Ballot*, and *Casting a Ballot*) on the **left panel**:
    1. In the *Check-In* tab:
        i. Set the Type of Check-in Equipment to Electronic,
        ii. And set the Number of Check-in Stations to 2,
    2. In the Voting a Ballot tab:
        i. Set the Number of Voting Machines (non-accessible) to 0,
        ii. Set the Number of Accessible Voting Machines to 1,
        iii. And set the Number of Hand-marked Ballot Voting Stations to 10.
    3. In the Casting a Ballot tab:
        i. Set the Type of Ballot Casting Equipment to Electronic Ballot Scanner,
        ii. And set the Number of Ballot Casting Stations to 1.



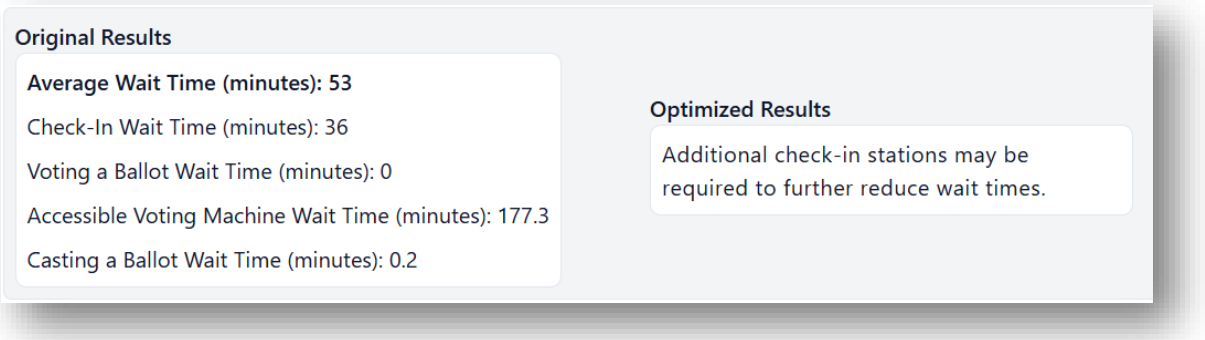
3. When all information is entered into the left panel, press the *Run Simulation* button.



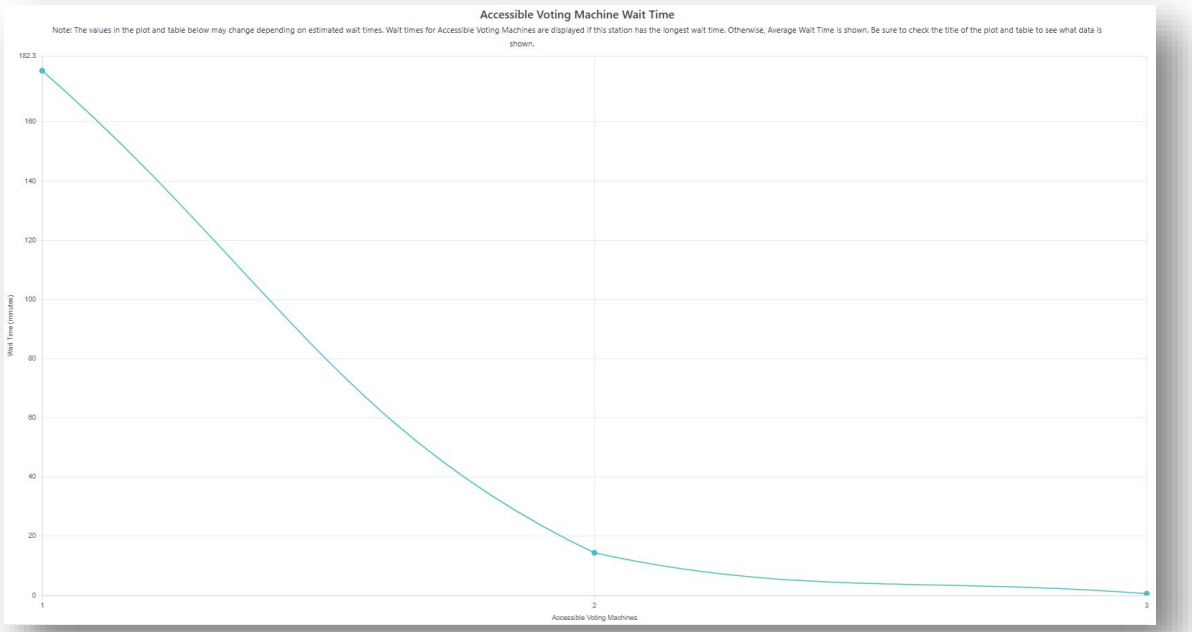
4. Now, look at the **right panel**. Results of the simulation model are presented numerically and graphically.



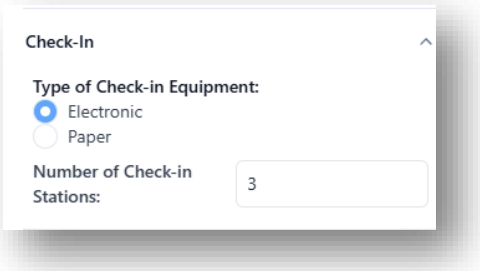
5. The results section presents two sets of information. The *Original Results* displays voter wait times based on the information entered in the **left panel**. The *Optimized Results*, with this allocation of resources, indicates that additional check-in stations are required to reduce voter wait times. When using this tool, the *Optimized Results* may show one of three options:
    1. An indication of which process requires additional resources,
    2. A note that the current resource allocation is sufficient to keep voter wait times under the Target Maximum Wait Time,
    3. Or a recommended number of accessible voting machines and the corresponding voter wait times statistics with the adjusted resource allocation.



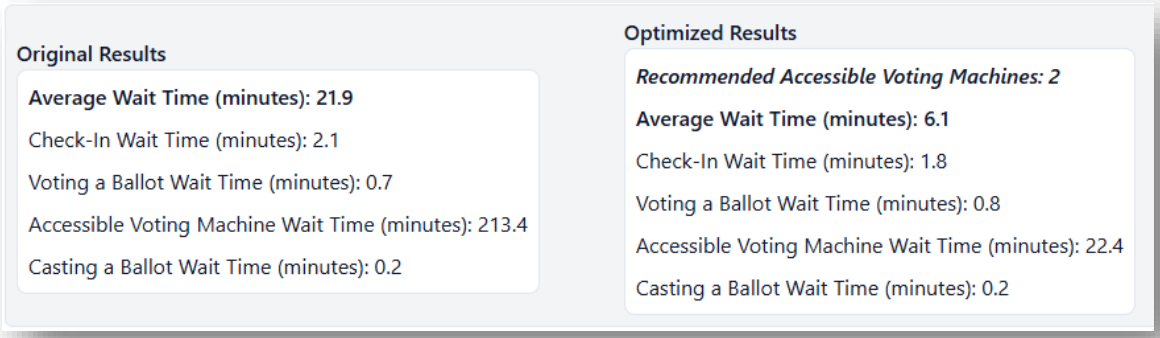
6. Observe the plot on the **right panel**. As the number of accessible voting machines increases (on the *X*-axis), the Accessible Voting Machine Wait Time decreases (on the *Y*-axis).


Accessible Voting Machine Wait Time
Note: The values in the plot and table below may change depending on estimated wait times. Wait times for Accessible Voting Machines are displayed if this station has the longest wait time. Otherwise, Average Wait Time is shown. Be sure to check the title of the plot and table to see what data is shown.
182.3
160
140
120
100
80
60
40
20
0
Wait Time (minutes)
1
2
3
Accessible Voting Machines

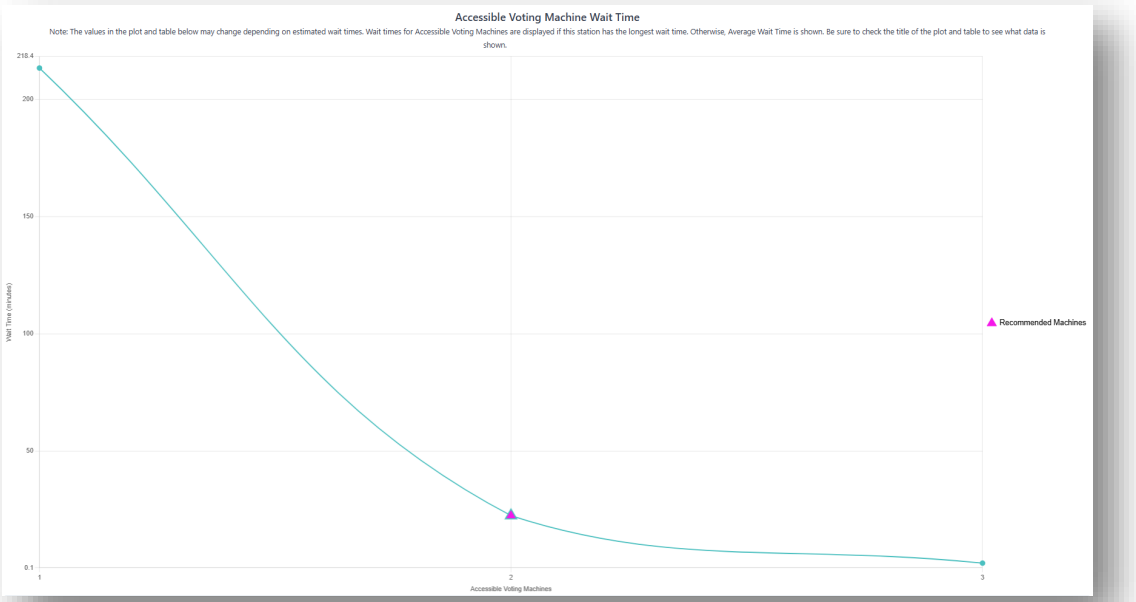
7. While the initial results suggest that additional accessible voting machines are needed to reduce wait times, we should first adjust the number of check-in stations so the Target Maximum Wait Time can be met. In this case, we will increase the Number of Check-in Stations to 3.



8. Now, press the *Run Simulation* button again to update the results in the **right panel**. The first change we will see is that the *Optimized Results* section is now populated with a recommended number of accessible voting machines and voter wait time results.



9. Notice that the plot below the results section has also been updated. Now, a purple triangular point on the graph indicates the voter wait time with the recommended number of accessible voting machines. Hover over points on the plot to see more information.



Left Panel: Settings

The left panel of the Accessible Voting Machines Calculator (Figure 1) contains settings, values, and preferences that can be adjusted to best reflect a particular voting location and voting process. Four menus are listed on the left panel including *Demographics*, *Check-In*, *Voting a Ballot,* and *Casting a Ballot*.

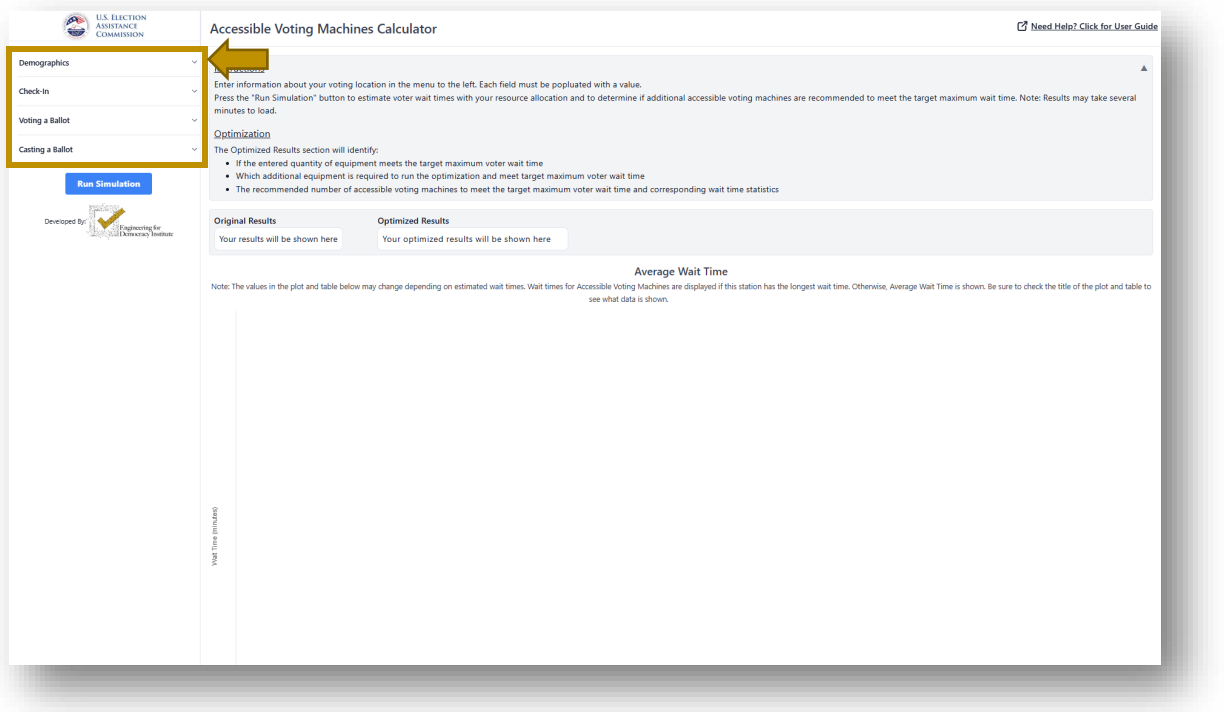


Figure 1. Left panel of the Accessible Voting Machines Calculator.

Demographics

The *Demographics* menu drop down is shown in Figure 2. This menu allows the user to input information regarding the number of voters expected to vote at a location, the percentage of voters that may require accessible voting equipment, the target maximum time that voters wait, and pattern of voter arrivals throughout the voting day.

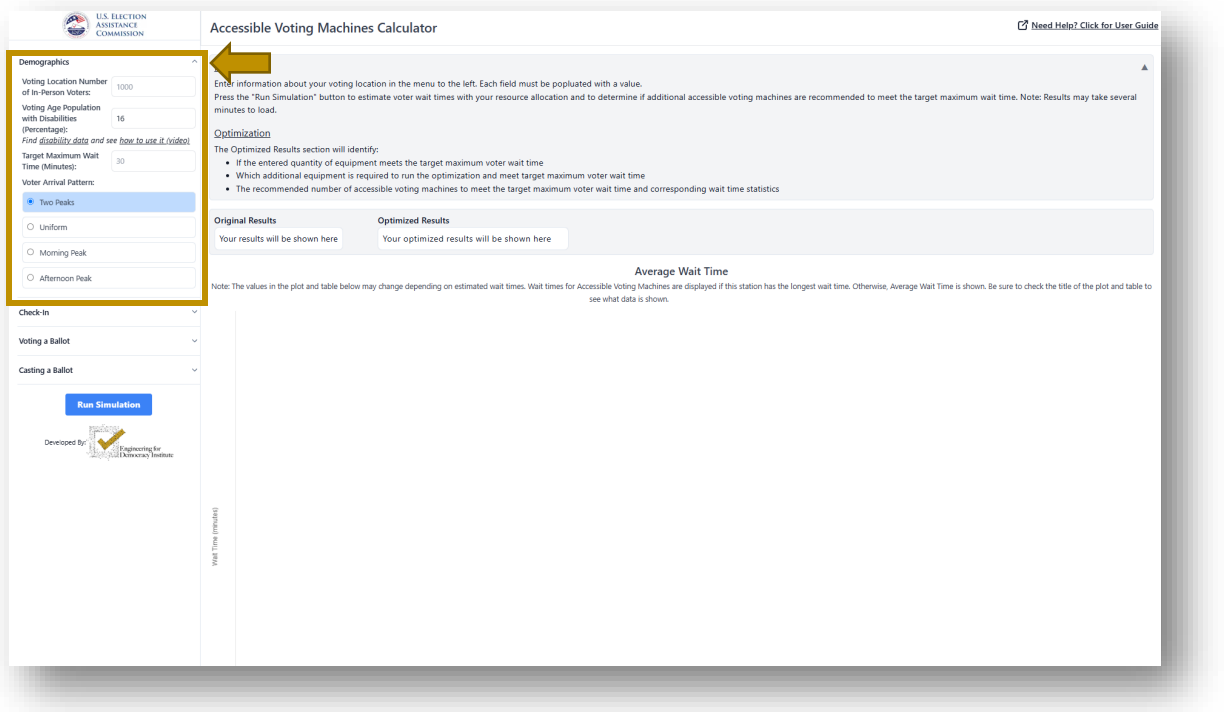


Figure 2. *Demographics* menu (left panel of application).

Voting Location Number of In-Person Voters:

This input represents the quantity of voters expected to vote in person on a single 13-hour voting day. Enter the expected number of voters to arrive in-person at a voting location.

Voting Age Population with Disabilities (Percentage):

The Voting Age Population with Disabilities (Percentage) input can be set to the percentage of individuals with disabilities within a jurisdiction according to the American Community Survey. A link to the United States Census Bureau is included at the bottom of the menu, which contains disability rates at county, city, and town levels. This value is internally adjusted by the calculator to account for the percentage of voters with disabilities who choose to vote in person.[3] By default, this value is set to 16, indicating that 16% of voters who turn out to vote may have disabilities. This default value is calculated from the 2022 American Community Survey and represents the average percentage of the voting-age population with

[3] It is assumed that 26% of voters with disabilities vote in-person. See: United States Election Assistance Commission, 2021a. New data: 17.7 million Americans with disabilities voted in 2020, a significant increase over 2016. URL: https://www.eac.gov/news/2021/07/07/new-data-177-million-americans-disabilities-voted-2020-significant-increase-over.

disabilities in counties across the US. To determine the 'Voting Age Population with Disabilities' percentage for your jurisdiction, you can utilize the EAC's video on Estimating the Voting Age Population with Disabilities, which provides step-by-step instructions. See Appendix A for a written version of these instructions.

Note: The proportion of the population with disabilities reported by the American Community Survey may include individuals who are ineligible to vote and should be used as a guideline rather than an absolute number. Additionally, certain groups are excluded or underrepresented in the data from the American Community Survey, such as individuals who are institutionalized.

Target Maximum Wait Time in Minutes:

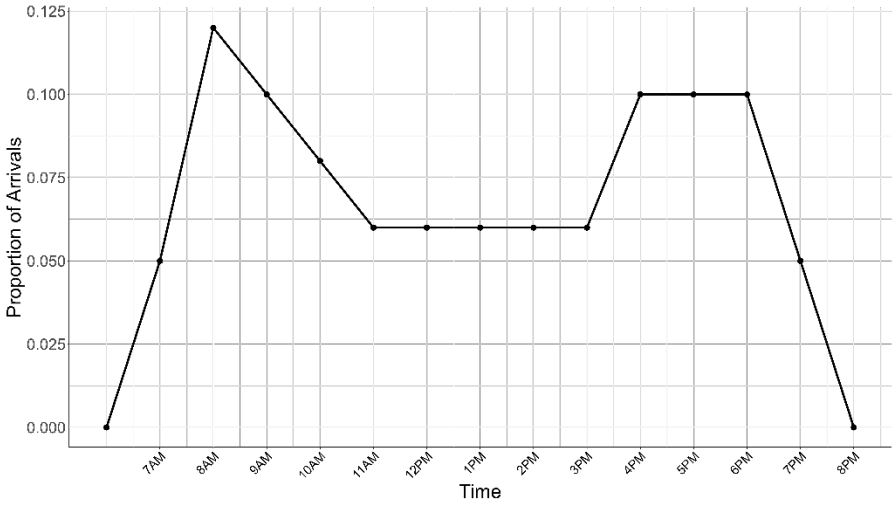
This value represents the longest amount of time that is acceptable for a voter to wait. This target value is used to generate a recommended quantity of accessible voting machines. If the value is set too low, the calculator cannot make a recommendation.

Voter Arrival Pattern:

The Voter Arrival Pattern option allows you to adjust how voters arrive at a voting location throughout a voting day to best represent voters in your jurisdiction. These arrival patterns are presented in more detail below:

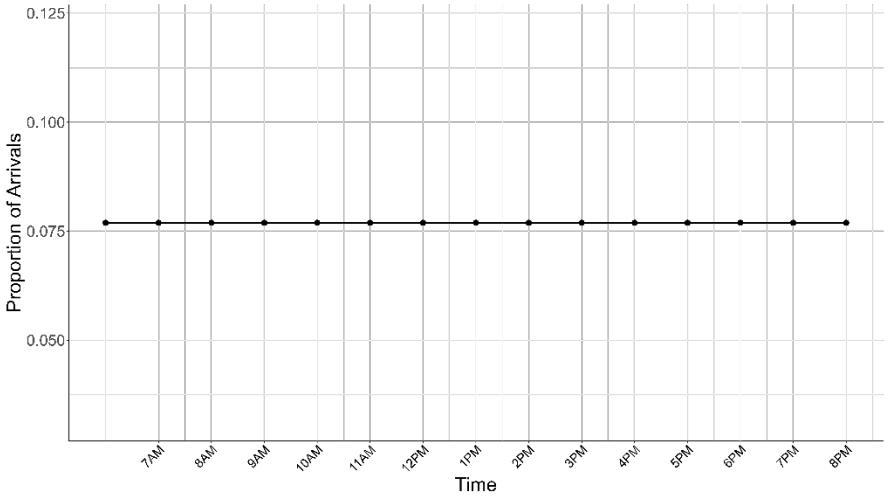
Two Peaks Arrival Pattern:

The Two Peaks Arrival Pattern exhibits a large proportion of voters arriving in the morning, between 7 AM and 10 AM, with another increase in voter arrivals from 4 PM to 7 PM.



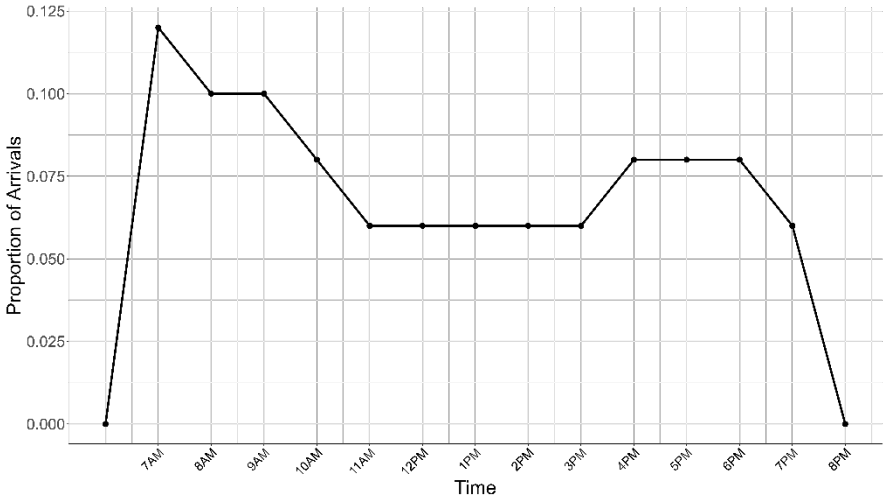
Uniform Arrival Pattern:

The Uniform Arrival Pattern exhibits a pattern of voter arrivals that are consistent throughout the voting day. The simulation will create some randomness in voter arrivals throughout the voting period to more accurately reflect actual voter arrivals, but the proportion of arrivals does not fluctuate throughout the voting period.



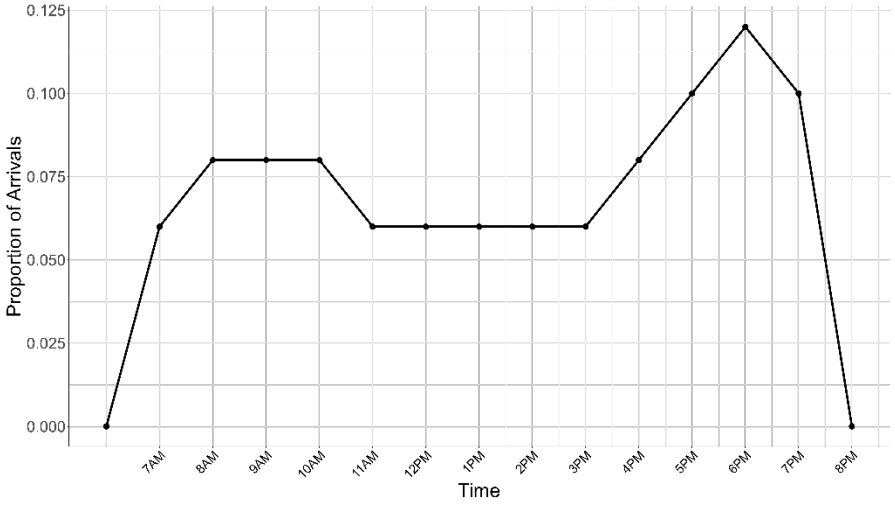
Morning Peak Arrival Pattern:

The Morning Peak Arrival Pattern exhibits a large proportion of voters arriving in the morning during the voting period between 7 AM and 10 AM. Voter arrivals then decrease and remain consistent between 11 AM and 3 PM, with a slight increase in arrivals from 4 PM to 6 PM.



Afternoon Peak Arrival Pattern:

The Afternoon Peak Arrival Pattern exhibits a large proportion of voters arriving from 4 PM to 7 PM. Voter arrivals remain relatively consistent throughout the morning and early afternoon of the voting period, with slightly more arrivals occurring from 8 AM to 10 AM.



Check-In

The *Check-In* menu is used to select the type of check-in equipment used and enter the number of check-in stations in the voting location (Figure 3).

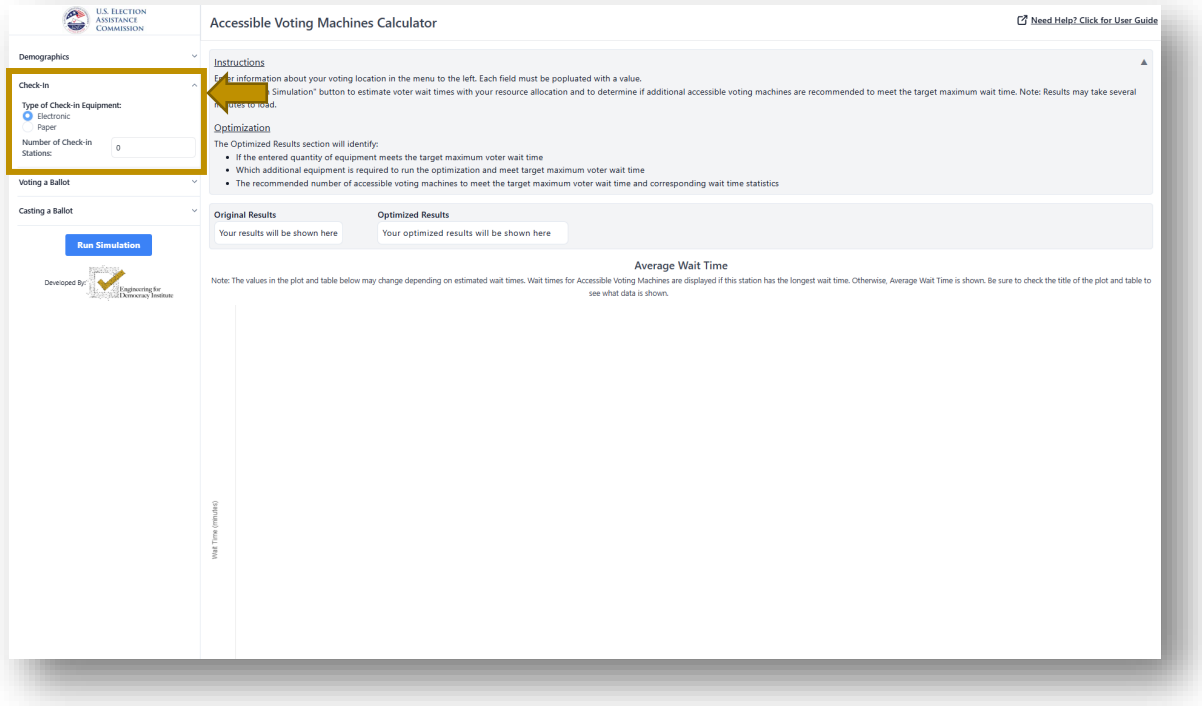


Figure 3. *Check-In* menu (left panel of application).

Select the Type of Check-in Equipment:

The Accessible Voting Machines Calculator includes data for both electronic poll books and paper poll books. The Type of Check-in Equipment option allows the user to indicate which type of equipment for check-in is used in their voting location. Processing times for each check-in equipment type, depending on the user's selection, are simulated with random distributions to better reflect voter behavior.

Number of Check-in Stations:

The Number of Check-in Stations input indicates the number of Electronic or Paper poll books at which voters can be checked in to vote. This number should represent the number of voters that may be checked in simultaneously and must be greater than zero.

Voting a Ballot

The *Voting a Ballot* menu is used to enter the number of devices and stations available to mark a ballot (Figure 4). The number of Voting Machines (non-accessible), Accessible Voting Machines, and Hand-marked Ballot Voting Stations may be entered. When using this menu, it is assumed that the Voting Machines (non-accessible) and Hand-marked Ballot Voting Stations do not offer accessibility features. The Number of Accessible Voting Machines is in addition to the quantity of Hand-marked Ballot Voting Stations and Voting Machines (non-accessible). The number of Accessible Voting Machines must have a value of at least 1. However,

the number of Hand-marked Ballot Voting Stations and Voting Machines (non-accessible) may be set to zero if one or neither of these types of equipment are used in a voting location.

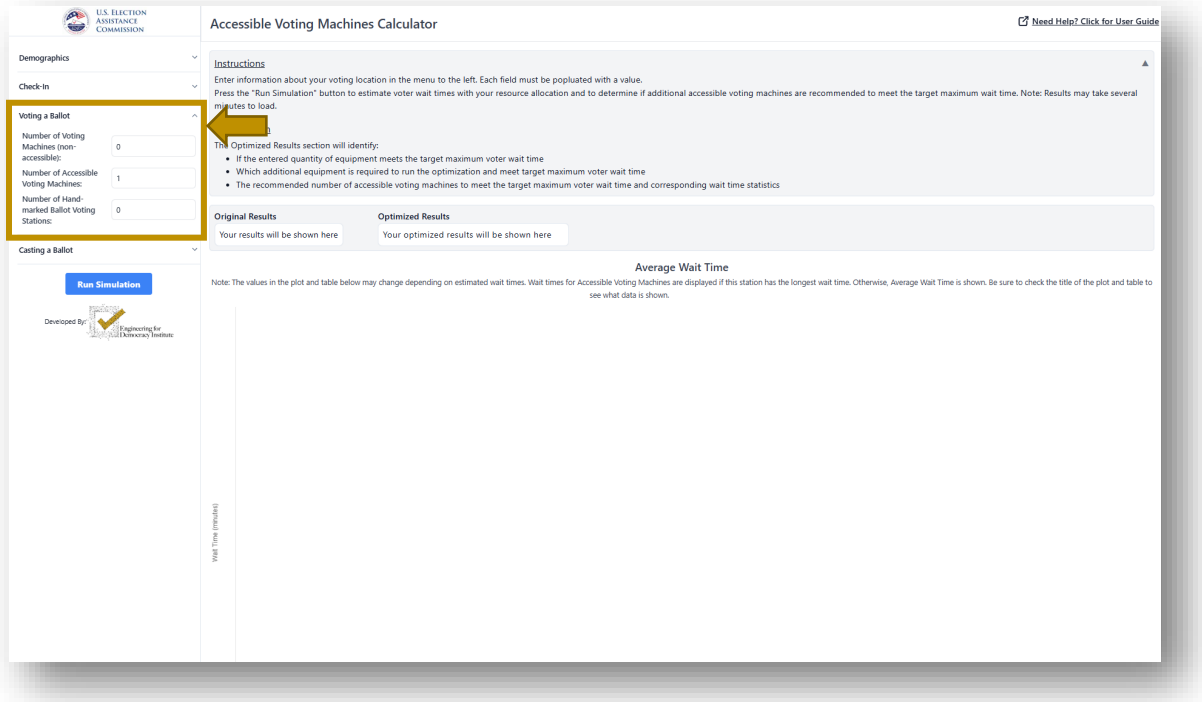


Figure 4. *Voting a Ballot* menu (left panel of application).

The time required to mark a ballot often differs between elections and between voting locations based on the number and complexity of ballot contests. Processing times estimated for ballot marking steps are determined from data collected from voting locations during several elections by the University of Rhode Island's Engineering for Democracy Institute (EDI).[4] However, these values may differ from expected ballot marking times due to variations in ballot style and contest composition.

To represent ballot marking by voters with disabilities on accessible voting machines, ballot marking times are simulated with a longer randomly distributed processing time. This increase in ballot marking time aligns with academic literature exploring reading and writing tasks for individuals with disabilities, which identifies a 6-32.5% increase in task time.[5] Voter wait times are simulated assuming that all voters with disabilities will opt to use an accessible voting machine and voters without disabilities will opt to use non-accessible devices, regardless of the presence of a line.

[4] EDI is a research group that utilizes engineering techniques to model voting processes and provide recommendations for election planning and voting operations. URL: https://web.uri.edu/edi/

[5] See: Lee, M.S., Lyoo, C.H., Lee, M.J., Sim, J., Cho, H., Choi, Y.H., 2010. Impaired finger dexterity in patients with Parkinson's disease correlates with discriminative cutaneous sensory dysfunction. Movement Disorders 25. URL: https://doi.org/10.1002/mds.23304.
Low, E., Crewther, S.G., Ong, B., Perre, D., Wijeratne, T., 2017. Compromised motor dexterity confounds processing speed task outcomes in stroke patients. Frontiers in Neurology 8. URL: https://doi.org/10.3389/fneur.2017.00484.
Ramulu, P.Y., West, S.K., Munoz, B., Jampel, H.D., Friedman, D.S., 2009. Glaucoma and reading speed: The salisbury eye evaluation project. Archives of Ophthalmology 127. URL: https://doi.org/10.1001/archophthalmol.2008.523.
Spenceley, L.M., Wood, W.L.M., Valentino, M., Lewandowski, L.J., 2020. Predicting the extended time use of college students with disabilities. Journal of Psychoeducational Assessment 38, 279–290. URL: https://doi.org/10.1177/0734282919848588.
Steenbergen, B., Veringa, A., Haan, A.D., Hulstijn, W., 1998. Manual dexterity and keyboard use in spastic hemiparesis: A comparison between the impaired hand and the 'good' hand on a number of performance measures. Clinical Rehabilitation 12. URL: https://doi.org/10.1191/026921598670272626.

Casting a Ballot

The *Casting a Ballot* menu is used to identify the Type of Ballot Casting Equipment and the number of ballot casting stations (Figure 5).

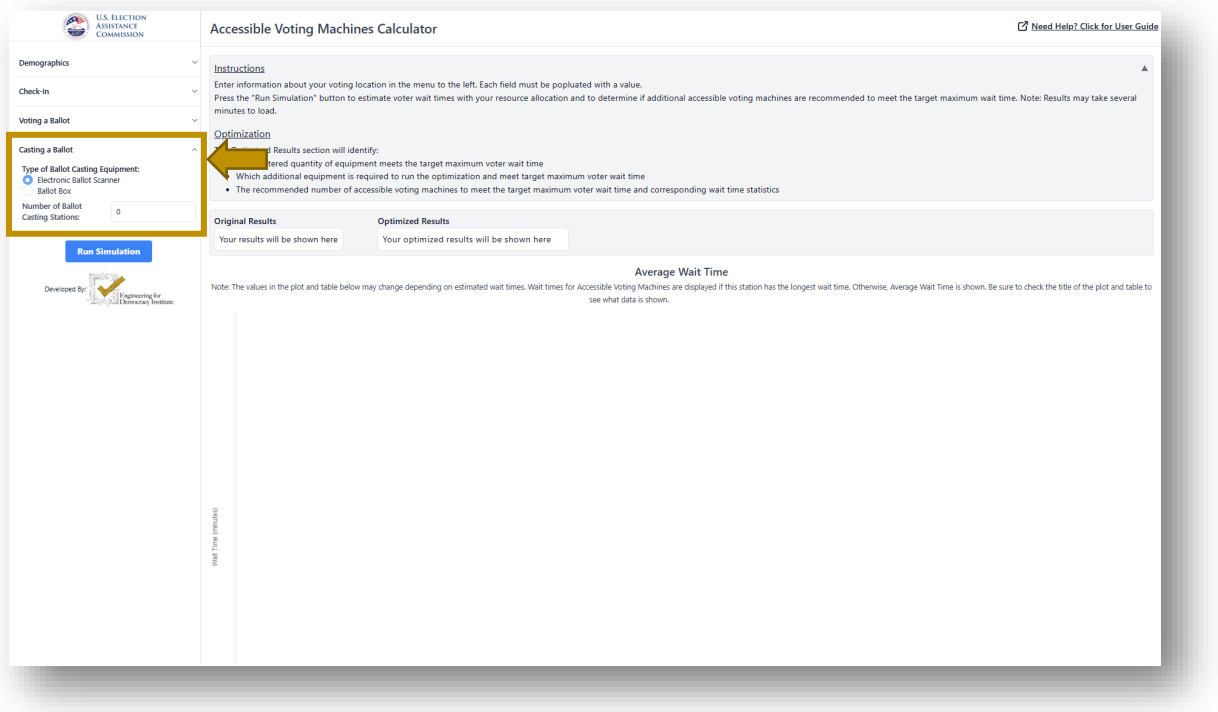


Figure 5. *Casting a Ballot* menu (left panel of application).

Select the Type of Ballot Casting Equipment:

The Accessible Voting Machines Calculator includes data for both electronic ballot scanners and ballot boxes. The Type of Ballot Casting Equipment option allows the user to indicate which type of equipment for casting a ballot is used in their voting location. Processing times for each equipment type, depending on the user's selection, are simulated with random distributions to better reflect voter behavior.

Number of Ballot Casting Stations:

The Number of Ballot Casting Stations input indicates the number of Electronic Ballot Scanner or Ballot Box stations at which voters can submit their ballot. This number should represent the number of voters that may cast a ballot simultaneously and must be greater than zero.

Right Panel: Outputs

The right panel of the Accessible Voting Machines Calculator contains analyses and results based on values entered in the left panel, as well as brief instructions and a description of the optimization output (Figure 6).

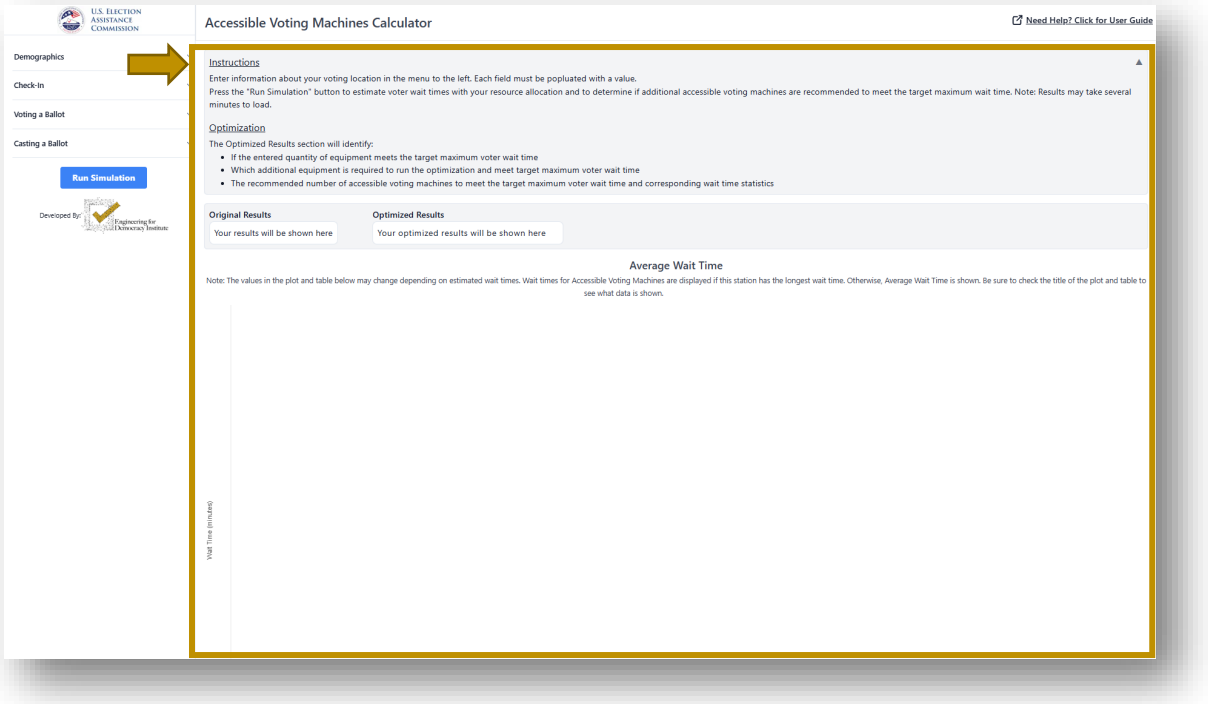


Figure 6. Right panel of the Accessible Voting Machines Calculator.

Results

Under the Instructions and Optimization information box, a set of results are displayed (Figure 7). These results contain the Original Results and the Optimized Results. The Original Results present the estimated Average Voter Wait Time (minutes), indicating the average amount of time that voters spend waiting throughout the entire voting process, and the estimated average wait times for each voting process.

Within the Optimized Results, three potential outputs may be observed depending on the inputs in the **left panel**. When using this tool, the Optimized Results may show one of three options:

1. An indication of which voting process requires additional resources,
2. A note that the current resource allocation is sufficient to keep voter wait times under the Target Maximum Wait Time,
3. Or a recommended number of accessible voting machines and the corresponding voter wait times statistics with the adjusted resource allocation.

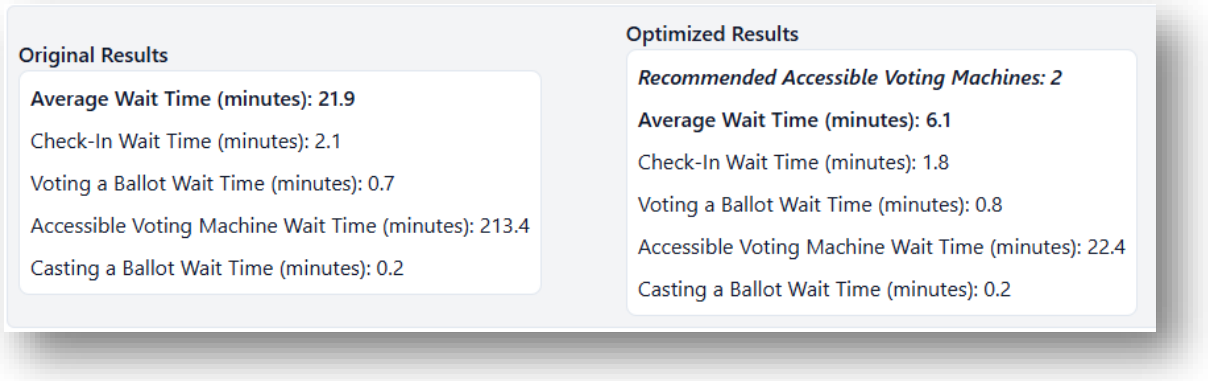


Figure 7. Original and Optimized Results

If Option 1 appears, the indicated voting process is preventing the simulated voter wait time from reaching the Target Maximum Wait Time due to a lack of resources. When Option 2 appears, then the values entered in the **left panel** are estimated to be sufficient to meet the Target Maximum Wait Time. When Option 3 appears, a set of simulation results are displayed in addition to the Original Results. In the Optimized Results output, the Recommended Number of Accessible Voting Machines is displayed. This value indicates the number of accessible voting machines required to ensure that both the Average Voter Wait Time and the wait time at the Accessible Voting Machines are less than the Target Maximum Wait Time. Utilizing this recommended value, a set of adjusted wait times are presented for the Average Wait Time as well as the wait times per voting process.

Plotting

At the bottom of the **right panel**, a plot is visible displaying estimated wait times at different quantities of accessible voting machines. When the Optimized Results provide a recommended number of accessible voting machines, a purple triangular point will be displayed on the plot indicating the quantity of resources and the estimated wait time with that number of accessible voting machines (Figure 8).

When running this simulation multiple times with differing inputs, the plot may change to display different information. If the estimated wait time for accessible voting machines is more severe than the average wait time, then the plot will display the Accessible Voting Machine wait time on the *Y*-axis. If the Average Wait Time is more severe, then the plot will display Average Wait Time on the *Y*-axis. Be sure to check the title of the plot to understand what data is being displayed. The *X*-axis of the plot will always display the Number of Accessible Voting Machines. Hover over the points on the plot to see additional information.

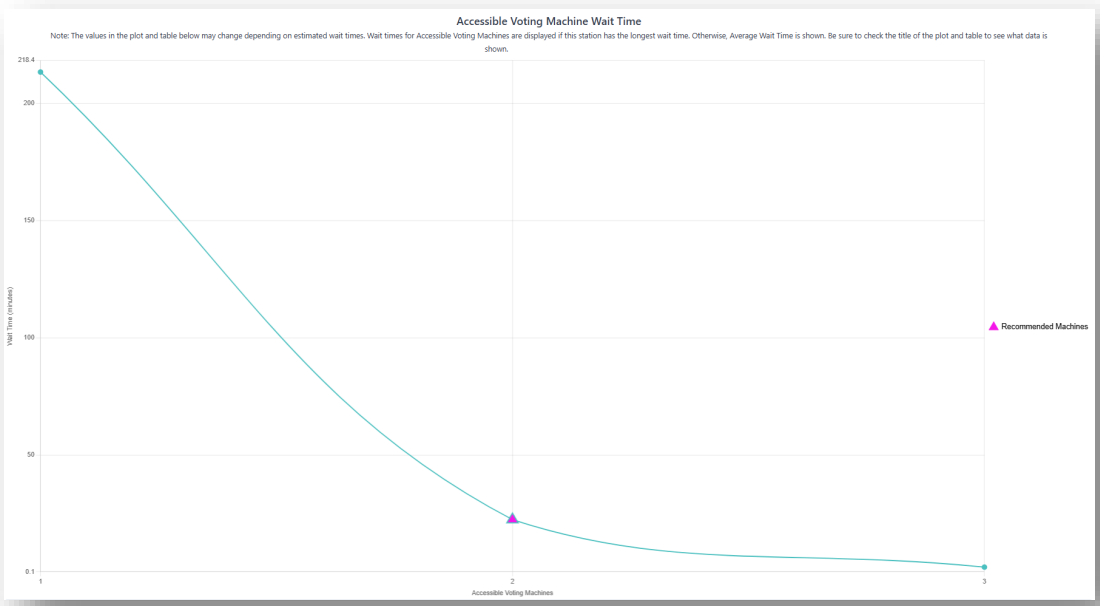


Figure 8. *Plotting* section (right panel of application).

Below the plot, a table of the plotted data is presented. This table shows the number of accessible voting machines in the left column and the estimated wait time in the right column. An example of this table is shown in Figure 9.

Accessible Voting Machine Wait Time Data

Machines	Wait Time (minutes)
1	213.40
2	22.40
3	2.10

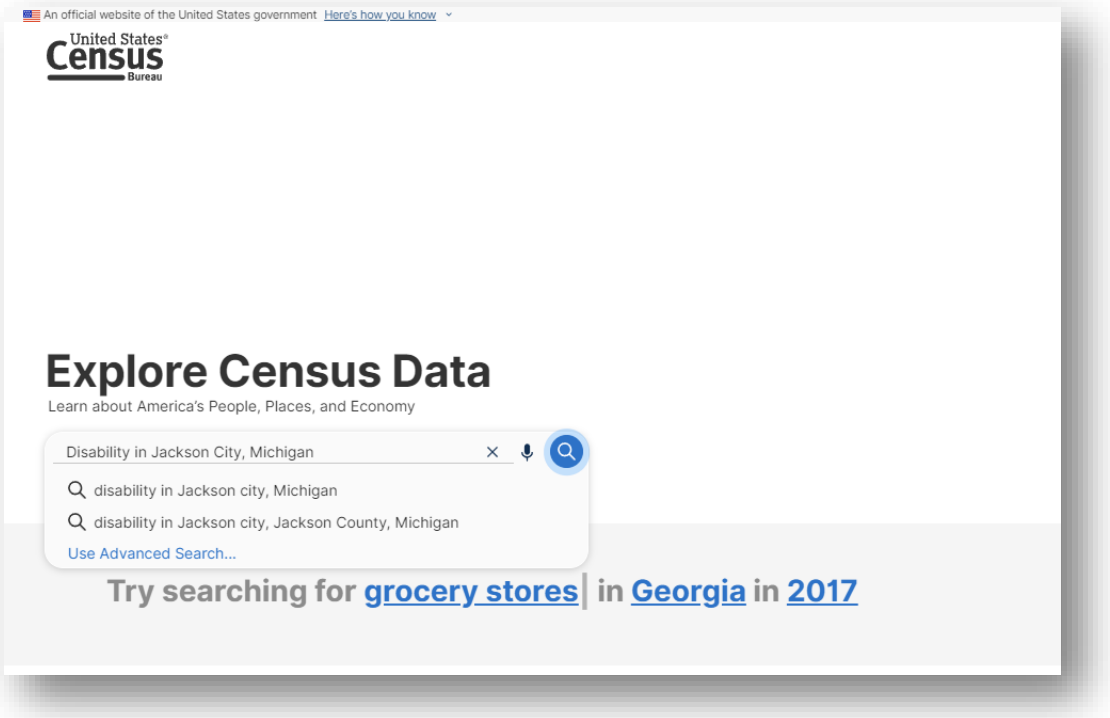
Figure 9. Table of wait time data (right panel of application).

Note

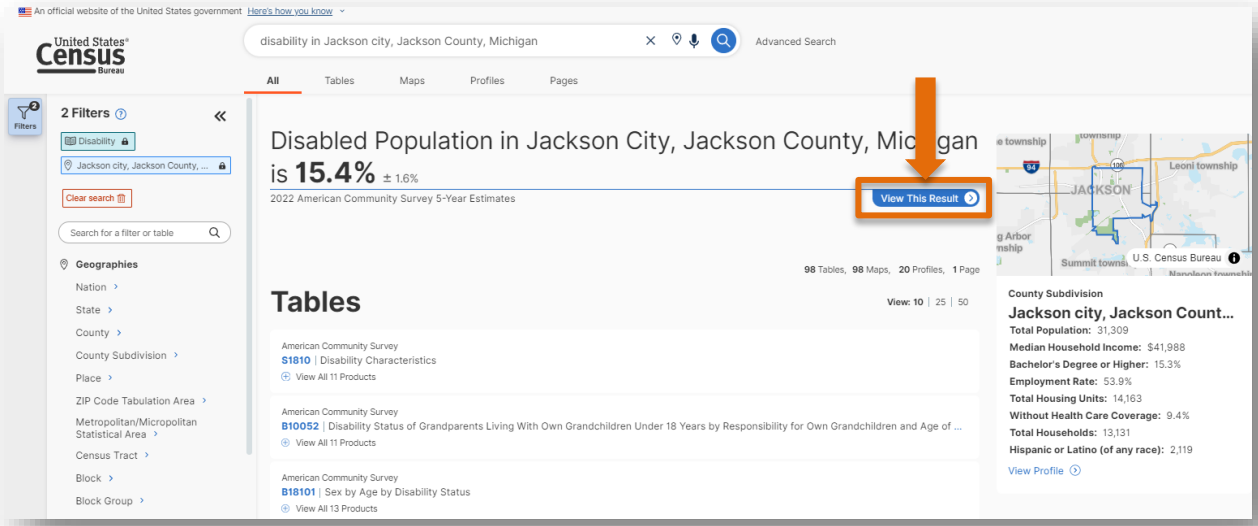
The values presented in this application are built with real election data; however, it is important to note it is unlikely that these models will exactly represent each individual voting process. For example, if a voting process contains different quantities of steps or drastically different processing times, then the presented values may not be accurate. With that said, this application can provide insights into the quantity of accessible voting equipment required to shorten voter wait times for all voters.

Appendix A: Determining the Percentage of Voters with Disabilities for a Jurisdiction

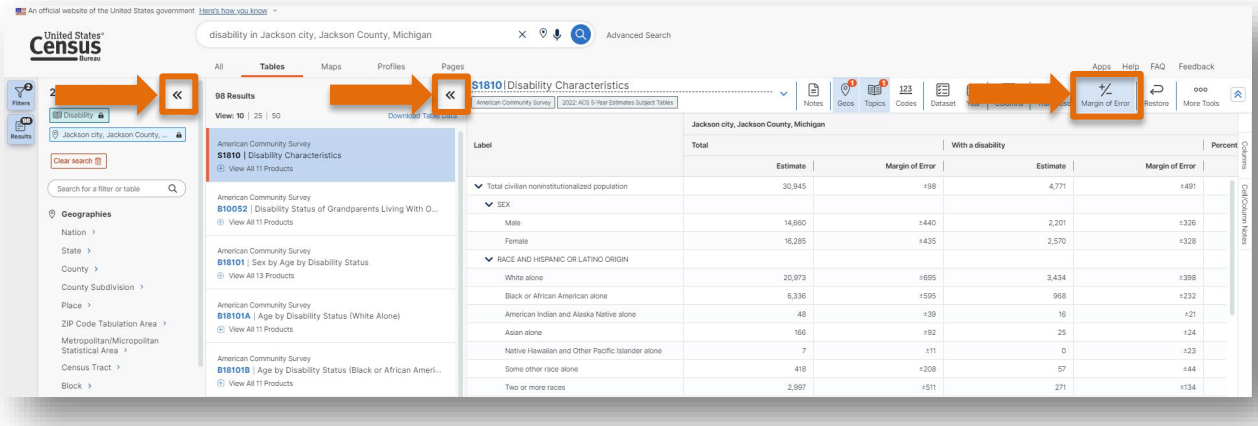
1. Navigate to data.census.gov,
2. Using the search bar, type in "Disability in" and the name of your jurisdiction. In the figure below, we are searching for "Disability in Jackson City, Michigan"



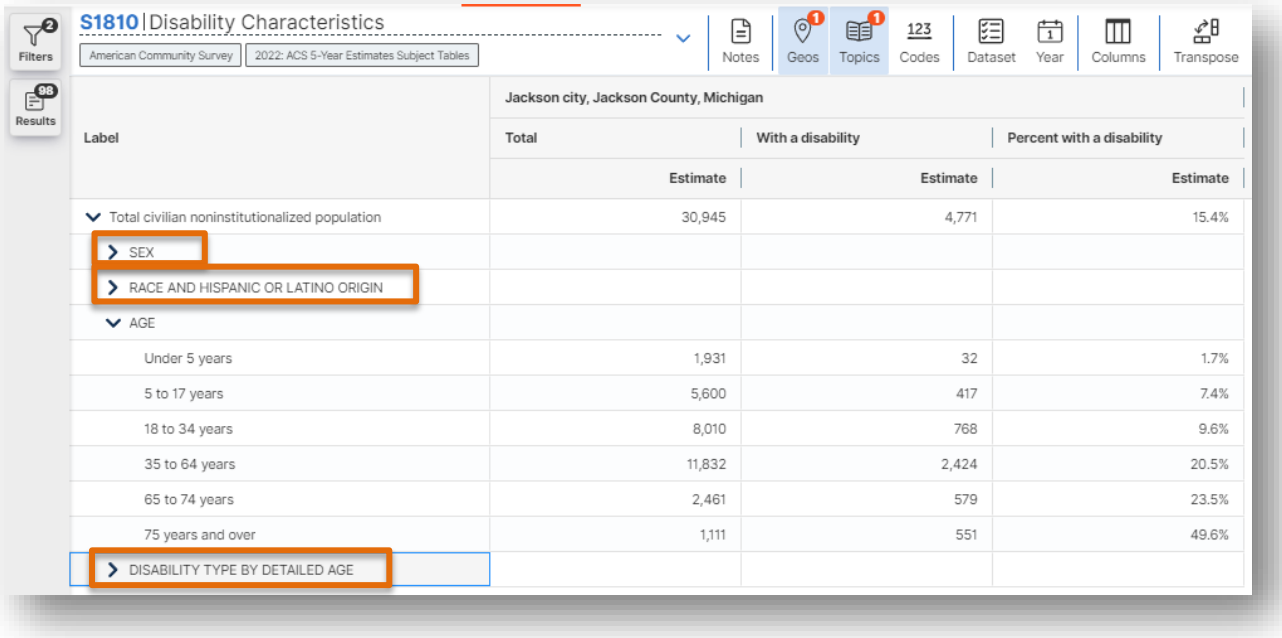
3. To make sure we see the correct results, use the dropdown menu under the search bar to select the correct search terms. In this case, we will select "disability in Jackson city, Jackson County, Michigan".
4. The page will now provide an overview of the data and a list of tables containing relevant information. To see the disability data that we need, click on the "View This Result" button under the overview.



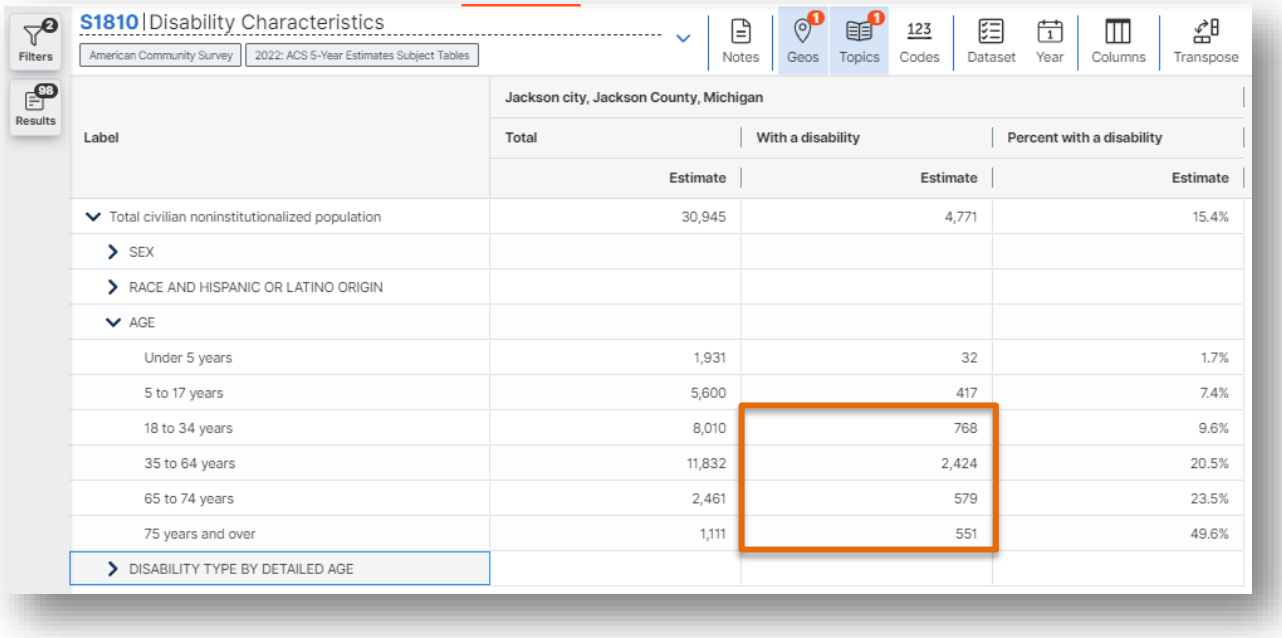
5. To simplify the new page, collapse the menus to the right side of the screen by clicking on the arrows at the top of each menu and deselect the "Margin of Error" button, as we do not need these data columns.



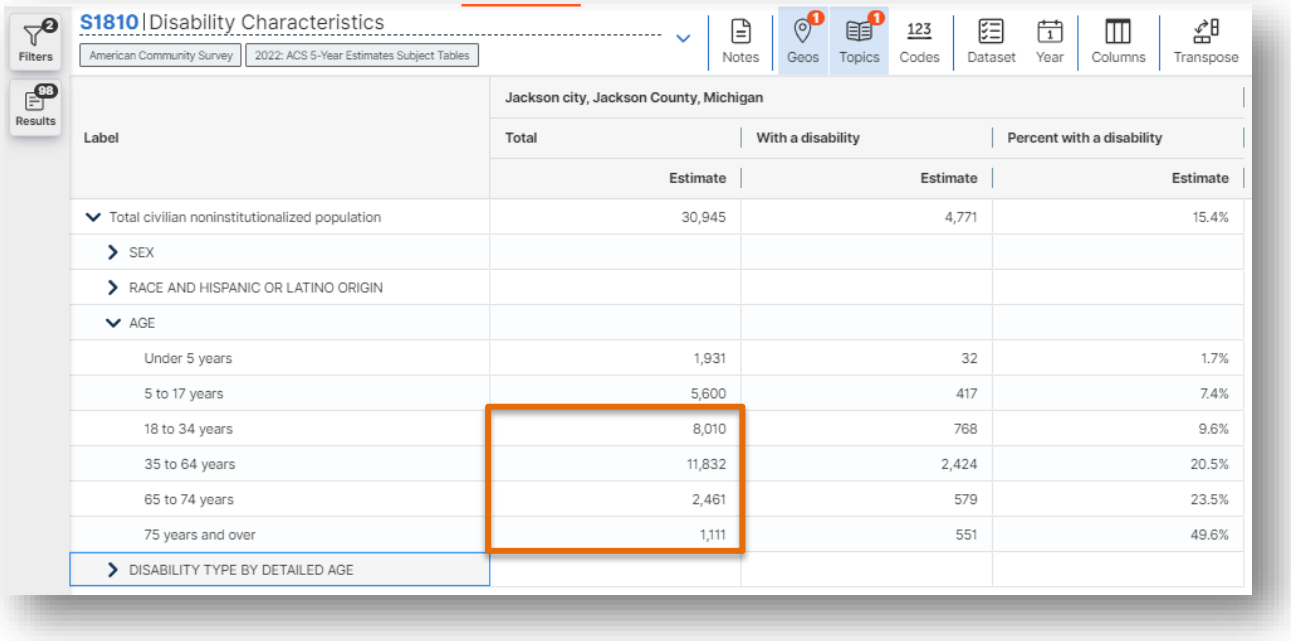
6. We can now hide rows of data that we do not need. Make sure that "AGE" columns are visible in the table and hide others that you do not wish to see in the table. Here, we have hidden "SEX", "RACE AND HISPANIC OR LATINO ORIGIN", and "DISABILITY TYPE BY DETAILED AGE".



7. To calculate the percentage of the voting-age population with disabilities, we first sum values in the "With a Disability" column for age ranges that represent eligible voters. In this case, 4,322 people over the age of 18 have disabilities in Jackson City, MI.



8. Next, we have to sum the total voting-age population in the "Total" column. This equals 23,414 people over the age of 18.



S1810 | Disability Characteristics

American Community Survey | 2022: ACS 5-Year Estimates Subject Tables

Filters 2 | Results 98 | Notes | Geos 1 | Topics 1 | Codes | Dataset | Year | Columns | Transpose

Label	Jackson city, Jackson County, Michigan		
	Total	With a disability	Percent with a disability
	Estimate	Estimate	Estimate
Total civilian noninstitutionalized population	30,945	4,771	15.4%
SEX			
RACE AND HISPANIC OR LATINO ORIGIN			
AGE			
Under 5 years	1,931	32	1.7%
5 to 17 years	5,600	417	7.4%
18 to 34 years	8,010	768	9.6%
35 to 64 years	11,832	2,424	20.5%
65 to 74 years	2,461	579	23.5%
75 years and over	1,111	551	49.6%
DISABILITY TYPE BY DETAILED AGE			

9. Finally, to calculate the percentage of the voting-age population with disabilities, we must divide the population with disabilities by the total population. In this case, we divide 4,322 by 23,414 which provides a proportion of 0.185, or 18.5%. This means that approximately 18.5% of eligible voters in Jackson City, Michigan have a disability.