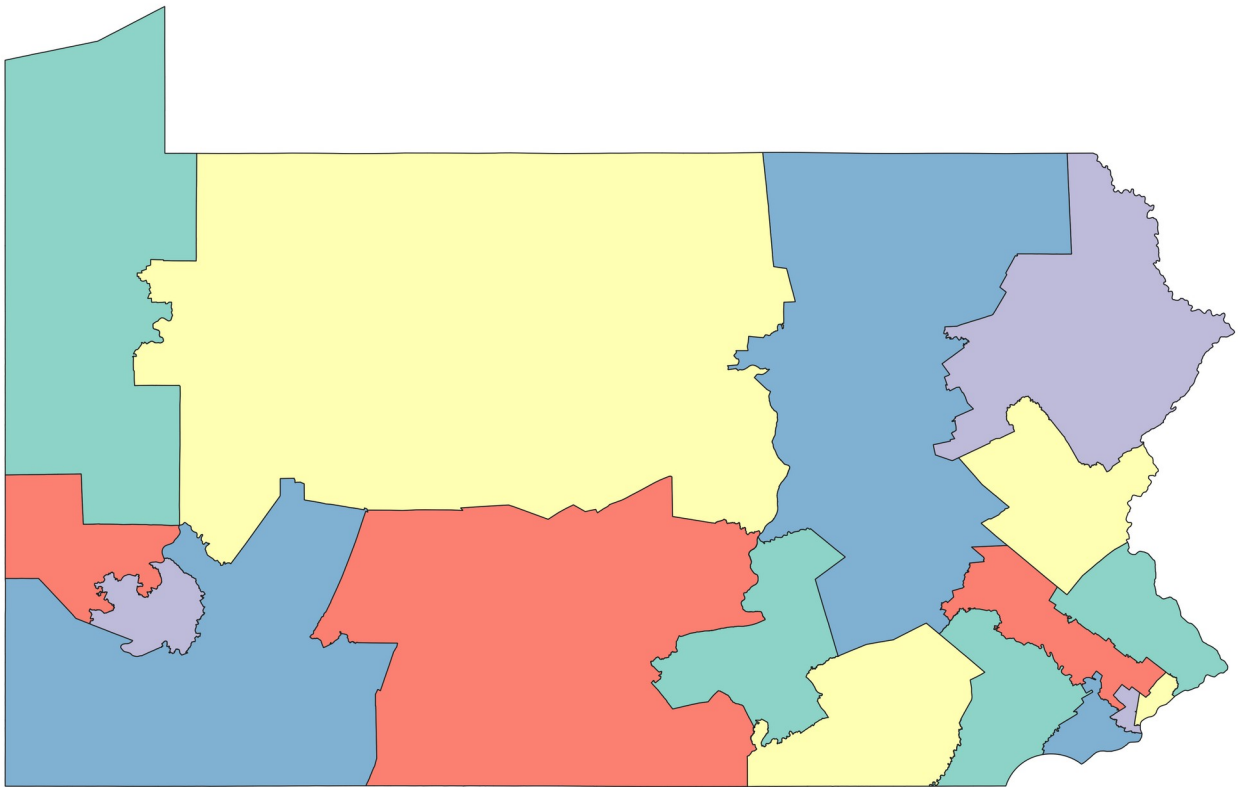


CITIZEN-SUBMITTED PLANS IN THE 2021 PENNSYLVANIA REDISTRICTING: THE VALUE OF PUBLIC INPUT



A Report by Concerned Citizens for Democracy
<https://ccfdpa.org/>

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Executive Summary

States follow a variety of processes for drawing district lines. In Pennsylvania, Congressional redistricting is done through the normal legislative process. Redistricting of the Pennsylvania House and Senate is done by the bipartisan Legislative Reapportionment Commission (LRC). Given Pennsylvania's different procedures for Congressional and legislative redistricting, the two halves of the 2021 process unfolded in wildly different ways, with different opportunities for citizen participation. The LRC held numerous public hearings and created a website for public comment. Citizens submitted almost 6,000 public comments and 83 complete legislative redistricting plans. Far fewer (19) Congressional redistricting plans were submitted to the legislature, likely due to less publicity around the Congressional program. House and Senate redistricting plans were created by the LRC, while citizen lawsuits culminating in *Carter v. Chapman* led to the Pennsylvania Supreme Court selecting the plaintiff's Congressional redistricting plan.

We downloaded all known citizen redistricting plans submitted to the LRC, to the Congressional redistricting web portal, and to the PA Supreme Court in *Carter v. Chapman*. We used Monte Carlo simulation, a standard method in redistricting analysis, to create ensembles of 10,000 randomized redistricting plans for Pennsylvania's House, Senate, and Congressional districts. Citizen-submitted plans are compared with these ensembles using measures of compactness, population deviation, election outcomes, and mean-median score (a measure of partisan bias).

Mean-median differences, an indicator of partisan bias, were on average lower for the legislative plans (0.88% for the Senate and 1.31% for the House) than for the Congressional public comment plans (2.36%). Average mean-median differences were the lowest (0.79%) for the 14 plans submitted by interested parties in *Carter v. Chapman*, indicative of the care that petitioners and *amici* took in crafting plans which stood a reasonable chance of being selected by the court as the enacted Congressional plan. The averages for all legislative and Congressional plans were positive, indicating varying degrees of Republican bias. The positive tilt is consistent with the widely held view that Democratic "self-packing" in urban areas tends to produce Republican-leaning plans. Finally, we note that the citizen-submitted plans performed significantly better on compactness than the ensembles and were about equivalent or slightly better on partisan bias (mean-median) than the ensembles.

This analysis demonstrates that citizen participation can significantly improve the redistricting process, and provide guidance to the LRC and the legislature about citizen preferences and the relative importance of competing plan criteria. As public awareness of redistricting has increased, more citizens have developed informed opinions and found ways to participate. Pennsylvania's acceptance of citizen-submitted redistricting plans serves as a model for future redistricting cycles. When redistricting officials seriously consider citizen input, it is generally believed that it leads to fairer district maps.

Introduction

Redistricting is the drawing of electoral districts for the purpose of electing representatives to Congress and the state legislatures. Redistricting has been politically contentious since the early days of the Republic,¹ but gerrymandering – redistricting for political advantage – increased dramatically after 2010.² Extreme gerrymanders in Pennsylvania and elsewhere focused citizen attention on the redistricting process in a way that was unusual 10 or 20 years earlier. With public attention high and redistricting software becoming easier to use and widely available, Pennsylvania in 2021 implemented a number of ways for citizens to become involved in the redistricting process, including through giving testimony and by submitting their own proposed redistricting maps.

This report summarizes citizen participation in Pennsylvania’s 2021 redistricting cycle. We assembled a repository of all known redistricting plans submitted to the Legislative Reapportionment Commission, the state legislature, and the PA Supreme Court in *Carter v. Chapman*, the case that resulted in Pennsylvania’s current Congressional redistricting plan.³ We briefly describe in layman’s language Monte Carlo simulation, a mathematical method that has become the standard for quantitative analysis of redistricting plans. We calculate standard metrics on the citizen-submitted plans, such as compactness and population deviation. Then we compare the citizen-submitted plans against hypothetical distributions created using Monte Carlo simulation.

Finally, we discuss the value of citizen participation, and how the opportunity for public participation might create more fair redistricting maps for future redistricting cycles.

Redistricting in Pennsylvania

States follow a variety of processes for drawing district lines. State legislatures are constitutionally responsible for redistricting, but may or may not do the redistricting directly. Where the state legislature retains control of the redistricting process, redistricting begins as a legislative bill that must be passed by both legislative chambers. In most states this goes to the governor for approval (and if vetoed, various outcomes are possible), but in five states the governor has no say, and cannot veto a redistricting bill. Some states have a political commission, which uses elected representatives or their designated appointees to form a commission that draws the plans. Some states use an advisory commission to create recommendations for the legislature, but the legislature still makes the final decisions for the

¹Erik J Engstrom, *Partisan Gerrymandering and the Construction of American Democracy*, Legislative Politics & Policy Making (Ann Arbor, MI: University of Michigan Press, 2016).

²Anthony J. McGann et al., *Gerrymandering in America: The House of Representatives, the Supreme Court, and the Future of Popular Sovereignty* (New York, NY: Cambridge University Press, 2016).

³“Redistricting Cases 464 MD 2021 and 465 MD 2021 | Cases of Public Interest | News & Statistics | Unified Judicial System of Pennsylvania,” accessed July 4, 2024, <https://www.pacourts.us/news-and-statistics/cases-of-public-interest/redistricting-cases-464-md-2021-and-465-md-2021>.

redistricting plans. Several states have a backup commission instead of an advisory commission, which will take over redistricting if the legislature fails to agree on a plan. Lastly, some states use independent commissions, comprised of citizens who are not legislators or public officials, to draw the district lines.⁴

Pennsylvania is unusual in having separate procedures for legislative and Congressional redistricting. Congressional redistricting is done through the normal legislative process, with the legislature creating a redistricting bill that must be passed by both the PA House and Senate, and then signed into law by the governor. The legislative redistricting plans (for both the PA House and Senate) are created by the Legislative Reapportionment Commission (LRC), a bipartisan commission comprised of the majority and minority leaders of both chambers of the legislature (or their deputies), along with a chairman who is agreed upon by the partisan leaders. In the event that a chairman cannot be agreed upon (which is typically the case), the chairman is appointed by the state Supreme Court.⁵

Conflicts over redistricting in Pennsylvania have spawned a number of court cases of national importance, including *Vieth v. Jubelirer*, a challenge to the 2001 Congressional redistricting. The lower courts found the districts to be malapportioned (that is, in violation of “one person, one vote”), and the state enacted a remedial map which satisfied the court on population equality. Plaintiffs argued that the new map was still a political gerrymander. The case went to the U.S. Supreme Court and was decided in 2004. The Court found that, while political gerrymandering was *in principle* justiciable (a reaffirmation of *Davis v. Bandemer* (1986)), the Court lacked a judicially manageable standard. Lacking such a standard, the Court let the lower court ruling stand.⁶

The 2011 Congressional redistricting was also challenged, although not before the enacted plan was used in the 2012, 2014, and 2016 Congressional elections. *League of Women Voters v. Commonwealth* was brought in the state courts and was expedited to be heard before the 2018 election. The Pennsylvania Supreme Court found that the map was a partisan gerrymander in violation of the Pennsylvania State Constitution, invalidated the map, and ordered a new map to be made.⁷ After the legislature and the governor were unable to agree on a new map, the PA Supreme Court had a special master draw a new Congressional map, which was put into effect in time for the 2018 election. This case reaffirmed that state courts in Pennsylvania can review gerrymandering cases.

⁴Justin Levitt and Doug Spencer, “Who Draws the Lines?,” All About Redistricting, accessed September 18, 2024, <https://redistricting.ils.edu/redistricting-101/who-draws-the-lines/>.

⁵“Pennsylvania Redistricting,” Pennsylvania Senate Democrats, accessed July 4, 2024, <https://pasenate.com/redistricting/>.

⁶*Vieth v. Jubelirer*, Cornell Law School: Legal Information Institute (U. S. Supreme Court 2004), <https://www.law.cornell.edu/supct/html/02-1580.ZS.html>.

⁷“League of Women Voters of Pennsylvania v. Commonwealth of Pennsylvania” (Brennan Center for Justice, October 29, 2018), <https://www.brennancenter.org/our-work/court-cases/league-women-voters-pennsylvania-v-commonwealth-pennsylvania>.

Given Pennsylvania's different procedures for Congressional and legislative redistricting, the two halves of the 2021 process unfolded in wildly different ways, with different opportunities for citizen participation. For the 2021 redistricting cycle, the Legislative Reapportionment Commission was composed of the four partisan legislative leaders: Majority Leaders Sen. Kim Ward (R) and Rep. Kerry Benninghoff (R), and Minority Leaders Sen. Jay Costa (D) and Rep. Joanna McClinton (D). The state Supreme Court appointed Mark A. Nordenberg, Chancellor Emeritus of the University of Pittsburgh, as the fifth member after the commission couldn't agree on a fifth member.⁸

Redistricting bodies use the Public Law 94-171 redistricting data published by the U.S. Census Bureau. However, USCB provides assistance to states that decide to count prisoners at a previously known address for the purpose of redistricting. The LRC decided early on to use prison reapportionment data as opposed to the P.L. 94-171 data.⁹ The prison reapportionment data counts incarcerated people in the districts of their last known address instead of at the prison where they currently reside. This decision aimed to protect Black and Latino communities, which have disproportionately high rates of incarceration, from losing political power to the rural, predominantly white communities where the prisons were most often located¹⁰. Prison reapportionment was opposed by Republican members of the LRC, and was one element of a broad legal challenge brought by Rep. Kerry Benninghoff against the LRC's final plan, a challenge which was ultimately rejected by the state supreme court. However, the Republican-controlled legislature did *not* use the prison reapportionment data for Congressional redistricting; so not only did the state use different processes for legislative and Congressional redistricting, it also used different Census data (albeit slightly so).

The LRC held numerous public hearings on Senate and House redistricting, and also created a website for public comment. From April 26th, 2021 until February 4th, 2022, the LRC held 25 in-person public hearings, which were live-streamed and included opportunity for remote participation¹¹. These hearings gave citizens and organizations that were concerned about and engaged in the redistricting process an opportunity to give testimony. The commission received almost 6,000 public comments before the January 18th, 2022 deadline.¹² Citizens were able to submit redistricting plans as file uploads or as [DistrictBuilder](#) or [Dave's Redistricting App](#) (DRA) links (as well as narrative testimony without a proposed redistricting plan) through the LRC

⁸Max Baer, "Re: Pennsylvania Legislative Reapportionment Commission," May 3, 2021, <https://www.redistricting.state.pa.us/resources/press/2021-05-03%20Supreme%20Court%20appoints%20Mark%20Nordenberg.pdf>.

⁹"August 24th - Legislative Reapportionment Commission Approves Resolution Regarding Prisoner Data Reallocation," August 24, 2021, <https://www.redistricting.state.pa.us/commission/article/1070>.

¹⁰"Taking on Prison Gerrymandering, Formerly Incarcerated Voters and the NAACP-PA File an Amicus Brief Supporting PA State House and Senate Maps," *The Public Interest Law Center* (blog), March 11, 2022, <https://pubintl.org/cases-and-projects/taking-on-prison-gerrymandering-formerly-incarcerated-voters-and-the-naacp-pa-file-an-amicus-brief-supporting-pa-state-house-and-senate-maps/>.

¹¹"Hearings," Pennsylvania Redistricting, n.d., <https://www.redistricting.state.pa.us/commission/hearings>.

¹²"Deadline for Public Comment," Pennsylvania Redistricting, January 15, 2022, <https://www.redistricting.state.pa.us/commission/article/1094>.

website. The LRC approved the final redistricting plans on February 4th, 2022¹³.

The commission voted on preliminary House and Senate maps separately, and held a vote to approve both final maps at the same time. The preliminary House map moved forward by a 3-2 vote, with the Democratic representatives and the independent chair voting in favor and the Republican representatives voting against.¹⁴ House Majority Leader Kerry Benninghoff said, “I see this map as extremely partisan gerrymandered.”¹⁵ However, PlanScore scores the plan as being a balanced plan (no advantage for either party) on four widely used metrics of partisan asymmetry.¹⁶

The commission approved the preliminary Senate map by a unanimous 5-0 vote.¹⁷ The map received an overall grade of a B from Princeton Gerrymandering Project, with a B for partisan fairness, indicating little political bias that overly favors one party, but an F for competitiveness. The map received an A for geographic features.¹⁸ The final House and Senate maps were approved together on a 4-1 vote, with Rep. Benninghoff as the only holdout.

The Congressional redistricting plan is typically drawn by the state legislature and sent to the governor, who can approve or veto the legislature’s plan.¹⁹ Pennsylvania lost one Congressional seat in 2021 due to a lack of population growth relative to other states, leaving it with 17 seats.²⁰ The lost seat made it very likely that, barring retirements, some incumbents would end up running against each other.

Like the LRC, the legislature also accepted redistricting map submissions via a public comment website. The legislature received far fewer submissions than the LRC — only 19 maps — likely due to less publicity around the Congressional program and to the fact that their submission system was much less user-friendly than the LRC’s. A board member who submitted a redistricting map on behalf of CCFD reported that she and other citizen map designers found

¹³“LRC Adopts 2021 Final Plans,” Pennsylvania Redistricting, February 4, 2022, <https://www.redistricting.state.pa.us/commission/article/1096>.

¹⁴Kate Huangpu and Angela Coulombis, “Democrats Could Make Sizeable Gains in Pennsylvania Legislature under Proposed New Maps,” December 16, 2021, <https://www.spotlightpa.org/news/2021/12/pennsylvania-redistricting-state-house-senate-maps/>.

¹⁵Huangpu and Coulombis.

¹⁶PlanScore, “PlanScore: Pennsylvania,” PlanScore, accessed January 27, 2025, <https://planscore.org/pennsylvania/#!2022-plan-statehouse-eg>.

¹⁷Mark Nordenberg, “Meeting of the Pennsylvania Legislative Reapportionment Commission Approval of a Final Plan,” February 4, 2022, <https://www.redistricting.state.pa.us/resources/Press/2022-02-04%20Chairmans%20Statement.pdf>.

¹⁸PGP, “Redistricting Report Card - Pennsylvania 2022 Final State Senate Map - Enacted,” Gerrymandering Project, December 16, 2023, <https://gerrymander.princeton.edu/redistricting-report-card/?planId=recNBn0tcg8xEtfv2>.

¹⁹Justin Levitt and Doug Spencer, “Pennsylvania: State Summary,” All About Redistricting, accessed September 18, 2024, <https://redistricting.ils.edu/state/pennsylvania/>.

²⁰Kate Huangpu, “Congressional Map Picked by Pennsylvania Supreme Court Unlikely to Dramatically Alter Partisan Balance,” February 23, 2022, <https://www.spotlightpa.org/news/2022/02/pennsylvania-redistricting-congressional-map-supreme-court-pick/>.

the Citygate GIS web mapping portal to be user-unfriendly and bug-ridden.²¹ Many therefore used DRA or other external tools to design their maps, instead. However, while the LRC portal allowed public commenters to link to a map created in DRA, the Congressional redistricting portal required them to download their DRA maps and then upload them to the public comment portal. They then discovered that the site mangled or failed to process maps uploaded in most standard redistricting data formats. Tech support personnel were deluged with requests for help, and the legislature had to extend their deadline for mapping submissions in order to ensure that citizens who intended to submit maps had enough time to prepare and submit their plans.²² Many mappers frantically struggled to hand-copy their intricate designs, census block by census block, at the last minute. Evidence from the submission numbering system suggests that there had been more than 200 attempts to submit maps, but, due to the difficulty of the process, only 19 were successfully completed.

The Republican majority in the state legislature ultimately produced a map that was vetoed by Democratic Governor Tom Wolf, who argued that the map was gerrymandered in favor of Republicans. While the legislature and the Governor were disagreeing over the Congressional map, a case now called *Carter v. Chapman* was wending its way through the state courts. The Carter plaintiffs, arguing that the legislature and the Governor would not be able to create a map in time for the 2022 election, took the unusual step of challenging the *old* 18 seat map as unconstitutional because of the changed number of seats.

Originally filed as *Carter v. Degraffenreid*, the plaintiff argued that, because the Census data was late due to the COVID-19 pandemic, the legislature would not meet the December 2021 deadline for the map to be prepared for the 2022 election.²³ This suit was initially dismissed as premature in early October 2021, as a few months still remained for the legislative process to play out before candidates would need to file their paperwork for the 2022 primary elections. However, when the legislature and the Governor had still failed to enact a plan by December 2021, and candidate deadlines began to loom, *Gressman v. Degraffenreid* and *Carter v. Degraffenreid II* were filed on substantially similar grounds, challenging the *existing* 18 seat map. These cases were soon consolidated and became *Carter v. Chapman*.²⁴

The plaintiffs in this case pointed out that population shifts over the decade had caused the 18 seat Congressional map to violate both the one person, one vote required by the Constitution, and the updated federal apportionment requirement that Pennsylvania elect only 17 members to Congress.²⁵ The plaintiffs argued that the legislature had demonstrated its inability to create a constitutionally valid redistricting map in time for the next election. The court concluded that it

²¹Anne Hanna, "Personal Communication," November 10, 2024.

²²Jan Murphy, "House Panel Extends Deadline for Proposed Congressional Map Submissions," *PennLive*, December 3, 2021, <https://www.pennlive.com/news/2021/12/house-panel-extends-deadline-for-proposed-congressional-map-submissions.html>.

²³Carol Ann Carter et al., "Complaint," April 26, 2021.

²⁴Carol Ann Carter et al., "Petition for Review," December 17, 2021.

²⁵"Carter v. Chapman," *The American Redistricting Project*, October 3, 2022, <https://thearp.org/litigation/carter-v-chapman/>.

was tasked with enacting a redistricting map because, as in *LWV v. Commonwealth*, the legislature and the Governor could not agree on a map. The court decided to adopt the plan presented by the Carter Petitioners, subsequently referred to as the Carter Plan.²⁶

In spite of the lost Congressional seat, the Carter Plan attempted a “least-change” strategy of preserving as much as possible of the population cores of the then-current Congressional map, as the Court had already accepted that map as constitutionally valid. Analysis suggested that the Carter Plan had an expected outcome of 8 Democratic-leaning districts, 8 Republican-leaning districts, and 1 district with a slight advantage for the Democratic Party.²⁷ Princeton Gerrymandering Project (PGP) gave the Carter Plan an overall grade of B, with a B for partisan bias and a C for geographic features.²⁸ The B for partisan bias was based on what PGP found to be a slight Democratic advantage in this map. It is worth noting that PGP’s assessment differed from the expert opinion that guided the court, which found a slight Republican bias to nearly all of the plans that it considered, including the plan submitted by the Democratic Governor. This is an almost unavoidable feature of Pennsylvania’s electoral geography, in which the more populous urban areas are much more heavily Democratic than the rural areas are Republican.

The Pennsylvania Supreme Court’s final decision was in favor of the Carter plaintiffs. The Carter Plan became the official Congressional redistricting plan, and was used in the 2022 Congressional elections.²⁹

Methods

This study analyzes Pennsylvania redistricting plans created by citizens and in some cases political actors. The Pennsylvania House and Senate district plans were downloaded from the LRC’s public comment portal. The Congressional redistricting plans came from a public comment portal created by the legislature, as well as plans submitted by plaintiffs and *amici* in the *Carter v. Chapman* court case. As discussed earlier, the LRC formally decided to use prison reapportionment data for the legislative redistricting process,³⁰ while the legislature used the unmodified P.L. 94-171 Census data for Congressional redistricting. Our analysis uses the relevant data set in each case, and all public comment plans are assumed to have used the correct data sources as well.

Redistricting plans were submitted in a variety of formats, including shapefiles (a form of geographic

²⁶Max Baer, “Majority Opinion Chief Justice Baer,” March 9, 2022, https://vhdsfh2oms2wcnsvk7sdv3so.blob.core.windows.net/thearp-media/documents/Majority_Opinion_-_C.J._Baer_3.9.22.pdf.

²⁷Huangpu, “Congressional Map Picked by Pennsylvania Supreme Court Unlikely to Dramatically Alter Partisan Balance.”

²⁸“Redistricting Report Card - Pennsylvania 2022 Final Congressional Map - Enacted,” accessed August 2, 2024, <https://gerrymander.princeton.edu/redistricting-report-card/?planId=recT95YHHudtpR3Fc>.

²⁹Huangpu, “Congressional Map Picked by Pennsylvania Supreme Court Unlikely to Dramatically Alter Partisan Balance.”

³⁰2021-10-14 LRC Data Release No. 2.

information system file that can be used to display districts on a map) and precinct or block assignment files. An assignment file is a simple text file that contains an identifier for each Census block or voting precinct and the district that it is assigned to. A complete redistricting plan has every block or precinct assigned to one and only one district. Some public comments included these computer files (shapefiles or assignment files). Others included plans created in publicly available redistricting websites, in which case we downloaded the redistricting plans from these sites. Legislative plans submitted using Dave's Redistricting app (DRA) were exported to precinct assignment files or block assignment files. Legislative plans submitted using DistrictBuilder as well as Congressional plans submitted through the legislature's public comment portal could only be exported as shapefiles, which show district boundaries only. These plans were converted into precinct or block assignment files using QGIS, an open source GIS software. In each case a point internal to the precinct/block was spatially intersected with the district layer, allowing us to determine which district each precinct/block falls into. This was then exported to a precinct/block assignment file.

Some commenters submitted Congressional redistricting plans to the LRC, which was only responsible for legislative redistricting. We attribute this to the poorly publicized Congressional redistricting public comment portal, which received a low number of submissions in comparison with the LRC's portal, and we included these plans in our Congressional analysis. We also made minor changes to some plans, changes that we believe are plausible and consistent with the submitters intentions. Some Congressional plans incorrectly used the LRC data files, which split some Census blocks to accommodate precinct boundaries. And some plans omitted an occasional precinct or block (at most one in any given plan), including several that left out a precinct in the offshore area of Lake Erie with zero population. We joined unassigned precincts or blocks to an adjacent district based on plausible assumption of designer intent. All plans, both the original submissions and our processed versions, are available at <https://github.com/ccfdpa/pa-citizen-redistricting-plans-2020>, with documentation of the choices we made in processing them in the repository README.

The analysis was conducted using the R statistical programming language and the [redist](#) package (with supporting packages from the same authors).³¹ The redist package was created specifically to analyze redistricting plans such as the citizen-submitted plans we are concerned with here. The package includes functions to calculate summary statistics on the redistricting plans, such as compactness, population deviation, partisan bias, etc.

Additionally, the redist package automates the import of precinct-level election results.³² The data includes vote counts from the 2016, 2018, and 2020 election years. Analysis can be distorted by local and district elections which feature unopposed candidates or highly skewed results, as a heavily Democratic or heavily Republican district may have no major party opposition candidate, or opposition voters may not cast votes in these elections. For evaluations of expected seats and

³¹Christopher T. Kenny et al., "Redist: Simulation Methods for Legislative Redistricting," R, 2022, <https://alarm-redist.org/redist/>.

³²Voting and Election Science Team, "2020 Precinct-Level Election Results" (Harvard Dataverse, October 11, 2024), <https://doi.org/10.7910/DVN/K7760H>; citation omitted for data years other than 2020.

partisan bias of a proposed redistricting plan, we use the average of all statewide races in Pennsylvania (e.g. Governor, US Senator) over these three election years. The statewide average two-party vote share over this period was 52% Democratic and 48% Republican, so Democrats would be expected to win more seats under a fair redistricting plan. How many more than for a 50/50 election depends upon how many competitive seats there are. Pennsylvania's "reponsiveness" is typically about 2.5, which means that a 52% Democratic vote share should yield about 55% Democratic seats (2.5 times 2%, plus 50%).

For Congressional plans, which are constructed out of Census blocks, election results from the Voting and Election Science Team (VEST) data were allocated from precincts to blocks based on population proportion; that is, a block with 15% of the encompassing precinct's population was allocated 15% of the votes cast at the precinct level for each major party candidate.

Monte Carlo Simulation

We evaluate the plans using Monte Carlo simulation, which has become a standard method in redistricting analysis.³³ Monte Carlo simulation is used to evaluate how unusual a case is when there are few or no other cases to compare it with. Monte Carlo simulation is *not* needed when a population exists for comparison purposes—for example, you can determine whether someone is short, tall, or average, by measuring a large group of people and comparing one person against the distribution of heights that you find. For redistricting, no such comparison group exists. Only one plan is ever legally enacted, and there may be very few serious contenders to compare it with. How unusual are any of these plans? If a Congressional election in Pennsylvania produces 13 Republican seats and 5 Democratic seats, as was the case for the 2016 elections, how unusual is that outcome? The redist package facilitates the creation of "ensembles" of hypothetical redistricting plans with which to compare actual or proposed plans. We created 10,000 randomized redistricting plans for Pennsylvania's House, Senate, and Congressional districts, then calculated summary statistics on these ensembles. Citizen-submitted plans are compared with these ensembles on measures of compactness, population deviation, election outcomes, and mean-median score (a measure of partisan bias).³⁴

³³Jowei Chen and Jonathan Rodden, "Unintentional Gerrymandering: Political Geography and Electoral Bias in Legislatures," *Quarterly Journal of Political Science* 8, no. 3 (June 27, 2013): 239–69, <https://doi.org/10.1561/100.00012033> is not the first academic paper to discuss Monte Carlo simulation, but is widely cited as making Monte Carlo simulation the go-to method in redistricting analysis; Daryl DeFord and Duchin, Moon, "Random Walks and the Universe of Districting Plans," in *Political Geometry*, ed. Moon Duchin, Ari Nieh, and Olivia Walch (Birkhäuser Basel, 2020), 341–81, <https://mggg.org/publications/political-geometry/17-DefordDuchin.pdf> is an accessible introduction aimed at the layperson.

³⁴All ensembles were created using precincts. Note that Congressional plans legally use block assignment files in order to achieve near-equality of population (legislative plans have a looser population equality requirement). Because of the computing time needed for Monte Carlo simulation using blocks, it was necessary to use precincts for the Congressional simulations. However, in the vast majority of cases, Congressional districts are constructed using whole precincts, with only a handful of precincts split in order to achieve population equality. The precinct-based ensemble should still provide a reasonable distribution for comparison of proposed Congressional redistricting plans.

Compactness

Compactness is a concept related to the shape of a district and often appears in law without being defined. There are many alternative ways to measure compactness, most of which try to express how similar the shape of the district is to an ideal shape, usually a circle. This study uses the Polsby-Popper measure of compactness, which expresses compactness as the ratio of the area of a district to the area of a circle with the same perimeter.³⁵ Polsby-Popper is widely used and was one of the measures considered by the court in *League of Women Voters v. Commonwealth* and *Carter v. Chapman*.

Population Equality

As population equality, or near-equality, is also a statutory and Constitutional requirement, we calculate population deviation for the submitted plans. The plan deviation is the *maximum* percentage deviation from population parity of any single district in the plan, where population parity is the population of an ideal district when the state's population is divided evenly over all districts.³⁶

Partisan Outcomes

We estimate partisan outcomes in the Congressional and legislative analyses below. The tables in this report show how many seats each party would win in a simulated election based on the results of previous elections, which, as mentioned above, are all statewide elections from 2016, 2018, and 2020. Using the election data, the two-party vote share is calculated. When the Democratic vote share is greater than 0.5 (50% of the votes), then that seat is awarded to the Democratic party, and is awarded to the Republicans if the Democratic vote share is less than 0.5. (By convention, political scientists usually report Democratic vote share in their analyses.)

Mean-Median Score

The final metric we consider is the mean-median score, a measure of partisan bias. The mean-median score is the difference between the mean and median vote share for a political party. The closer the score is to 0 (that is, the closer the mean and median vote share are to each other), the less the districts are skewed in favor of one party or the other.³⁷ In the redist package, mean-median is reported as a percentage, with negative scores favoring Democrats (that is, Democrats win more than their "fair share" of districts) and positive scores favoring Republicans.

For example, in the 2016 election (prior to the court-mandated redistricting of *League of Women Voters v. Commonwealth*), the Democratic vote share across Pennsylvania's 18 Congressional

³⁵Daniel D. Polsby and Robert D. Popper, "The Third Criterion: Compactness as a Procedural Safeguard against Partisan Gerrymandering," *Yale Law & Policy Review* 9, no. 2 (1991): 301–53.

³⁶"Calculates Maximum Deviation from Population Parity — Redist.Parity," accessed August 2, 2024, <https://alarm-redist.org/redist/reference/redist.parity.html>.

³⁷"Mean-Median Difference," PlanScore, accessed August 3, 2024, <https://planscore.org/metrics/meanmedian/>.

districts ranged from 29.8% to 90.2% (excluding 3 districts where a candidate ran unopposed). The mean (average) Democratic vote share across all districts was 45.6%. The median Democratic vote share across all districts was 40.0%. The difference was 45.6% - 40.0% = 5.6%. This number is positive, indicating that this redistricting plan favored the Republicans.

Note that a score of 0 does *not* mean that each party wins an equal number of seats. If one party received a majority of the statewide vote, it would be expected to win a majority of seats. Mean-median is a measure of how much a party under/overperforms the expected result. Another way of understanding this is that 50% plus mean-median gives the Democratic vote share necessary to obtain equal seats. The aforementioned mean-median of 5.6% for the 2011 Congressional redistricting means that Democrats would have to win 55.6% of the vote to win half (9 out of 18) of

Plan	Creator	Mean Compactness	Max Pop Deviation	D Seats	R Seats	Mean-Median
Bipartisan minimal variance plan	Brandon Bechtel	0.3268	< 0.01%	7	10	5.38%
CCFD ruleset - equal population	Anne Hanna	0.3779	< 0.01%	9	8	0.94%
Competitive Districts MP	Matthew Price	0.2388	0.01%	9	8	0.22%
Congressional No Muni Split .02 pop dev	Ruth Yeiser	0.2647	0.01%	10	7	0.52%
Democrats Favored	EJ Reihl	0.3420	0.01%	9	8	-1.45%
District Map V.1	Amanda Fogarty	0.3957	< 0.01%	10	7	0.79%
District Plan 3	Zeb Harshbarger	0.3309	0.01%	8	9	3.18%
Fair Compact Balanced Districts Plan	Colin Pietropaolo	0.3908	1.49%	8	9	3.83%
Holt Congressional Plan Version 0 -- 0 Person Deviation	Amanda Holt	0.2745	< 0.01%	8	9	2.78%
Holt Congressional Plan Version 1 -- 13 Person Deviation	Amanda Holt	0.3026	< 0.01%	8	9	2.85%
Map5	Thomas Kutz	0.3307	0.01%	8	9	4.22%
MattPriceRedistrictPlanA	Matthew Price	0.3317	0.01%	7	10	5.30%
PA Citizens' Map from Draw the Lines	Justin Villere	0.3879	< 0.01%	10	7	0.71%
PA Congressional*	RN	0.3736	7.05%	7	10	4.33%
PA Congressional Map using LACRA Provisions	Carol Kuniholm	0.3707	0.01%	9	8	1.37%
PA Congressional Map - Community Representative*	JS	0.3606	4.73%	7	10	4.70%
PA US House Redistrict	Griffin Tripp	0.2869	< 0.01%	9	8	1.21%
PA1	Kenneth Shirk	0.3072	0.10%	8	9	3.41%
Plan #1 - Bipartisan Plan	Nathan Rybner	0.2505	0.01%	8	9	4.13%
Reduced Bias Variant 2 Based on A.Holt "Map 0"	Michael Waxenberg	0.2677	< 0.01%	10	7	0.62%
Reduced Bias Variant Based on DTL "Citizen's Map"	Michael Waxenberg	0.3380	< 0.01%	10	7	0.71%
US House map*	JC	0.3247	1.13%	9	8	2.13%
Citizen Average		0.3261	0.67%	8.5	8.5	2.36%
Ensemble Average		0.2287	0.93%	8.6	8.4	2.32%
Enacted Plan	Carter Petitioners	0.3216	< 0.01%	10	7	0.71%

Table 1: Congressional Plans Submitted to House Republican Caucus Public Comment Portal or the LRC Public Comment Portal (the latter indicated by an asterisk)*

the seats in Congress. Mean-median also provides an estimate for the fraction of Republican seats at a 50/50 vote by multiplying by the responsiveness (~2.5 as mentioned earlier) and adding to 50%. So a mean-median of 5.6% means that at 50/50 vote, Republicans would be expected to win $50\% + (2.5 \times 5.6\%) = 64\%$ of the seats. In fact, in 2016 Republicans won 54.1% of the two-party statewide Congressional vote, for which an additional $2.5 \times 4.1\%$ gives 74% of the seats. This is very close to the 72.2% of Congressional seats actually won (13 out of 18).

Analysis of Citizen-Submitted Congressional Redistricting Plans

We first analyze the Congressional district plans. There were 22 citizen submissions of congressional redistricting plans, including 19 submitted to the Congressional redistricting web portal and 3 submitted (incorrectly) to the LRC. Table 1 shows plan metrics on average compactness, percent population deviation, number of Democrat (D) and Republican (R) seats (earned at the average 52% Democratic vote share), and the mean-median score. Average compactness over all plans was 0.3261 and population deviation was 0.67%. The average mean-median score was 2.36%, indicating 9.5 Republican seats at 50% vote share. The enacted plan was not as compact as the average citizen-submitted plan, but it had less than half as much bias. The collection of plans averaged 8.5 seats for both Democrats and Republicans at 52% Democratic vote share, which translates to 9.4 Republican seats and 7.6 Democratic seats for an evenly split vote, in good agreement with the mean-median score

Table 2 shows metrics for the 14 redistricting plans considered by the court in *Carter v. Chapman*. All but one of these plans achieved 1 person or 2 person deviation (11 and 2 plans,

Plan/Creator	Mean Compactness	Max Pop Deviation	D Seats	R Seats	Mean-Median
Ali	0.3524	0.65%	10	7	0.53%
Carter Petitioners (enacted plan)	0.3216	< 0.01%	10	7	0.71%
CCFD	0.3523	< 0.01%	10	7	0.68%
Citizen-Voters	0.3492	< 0.01%	9	8	1.36%
Congressional Intervenor – Resenthaler 1	0.3630	< 0.01%	9	8	1.01%
Congressional Intervenor – Resenthaler 2	0.3525	< 0.01%	9	8	1.02%
Draw the Lines PA	0.3786	< 0.01%	10	7	0.72%
Gov. Wolf	0.3808	< 0.01%	9	8	-0.59%
Gressman Math/Science Petitioners	0.3480	< 0.01%	10	7	0.62%
HB 2146 (Republican Legislator)	0.3213	< 0.01%	8	9	2.31%
House Democratic Caucus	0.2788	< 0.01%	11	6	-0.20%
Senate Democratic Caucus – Map #1	0.3149	< 0.01%	10	7	0.92%
Senate Democratic Caucus – Map #2	0.3346	< 0.01%	10	7	-0.51%
Voters of PA (Corrected)	0.3921	< 0.01%	8	9	2.53%
Carter Court Filings Average	0.3457	0.05%	9.5	7.5	0.79%
Ensemble Average	0.2287	0.93%	8.6	8.4	2.32%

Table 2: Congressional Redistricting Plans Submitted to *Carter v. Chapman*

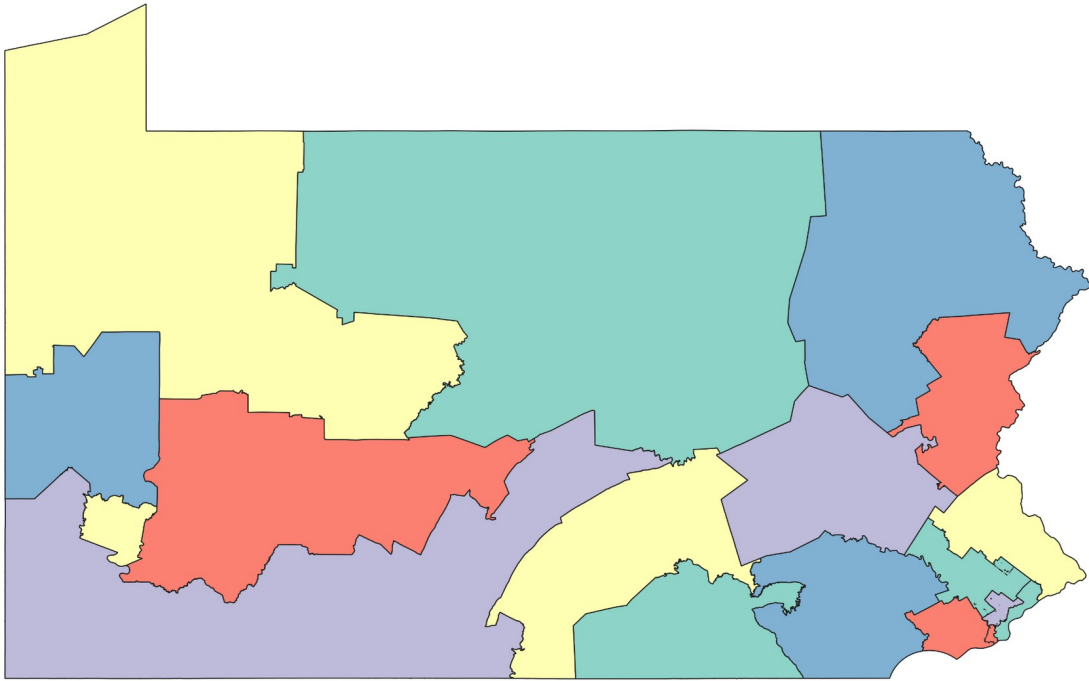
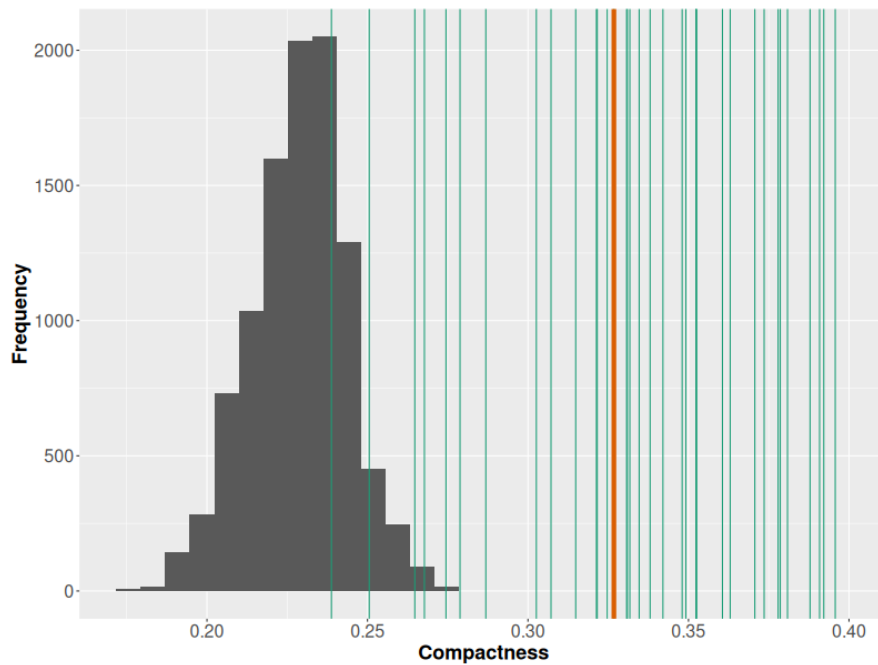


Figure 1: Example citizen-submitted Congressional redistricting plan (“Bipartisan Minimal Variance Plan”)

respectively), represented in the table as less than 0.01% deviation. These plans had an average compactness of 0.3457, 9.5 Democratic seats and 7.5 Republican seats for 52% Democratic vote share, and a mean-median score of 0.79%. For a 50/50 vote split, that mean-median score translates to 8.8 Republican seats. Of course, seats cannot be split, so with an odd number of Congressional seats (17), 8.8 seats means that these plans on average are likely to award the “extra” seat to Republicans.

In this and the legislative plan analyses, we select one citizen-submitted plan essentially at random to compare with other submitted plans and the ensembles. Figure 1 shows the Congressional district map for the “Bipartisan Minimal Variance Plan”. This plan has an average compactness score of 0.3268, a population deviation of less than 0.01%, and a mean-median score of 5.38%, which happens to be one of the most biased among the citizen submissions, indicating a substantial Republican lean of 10.8 seats at 50% vote.

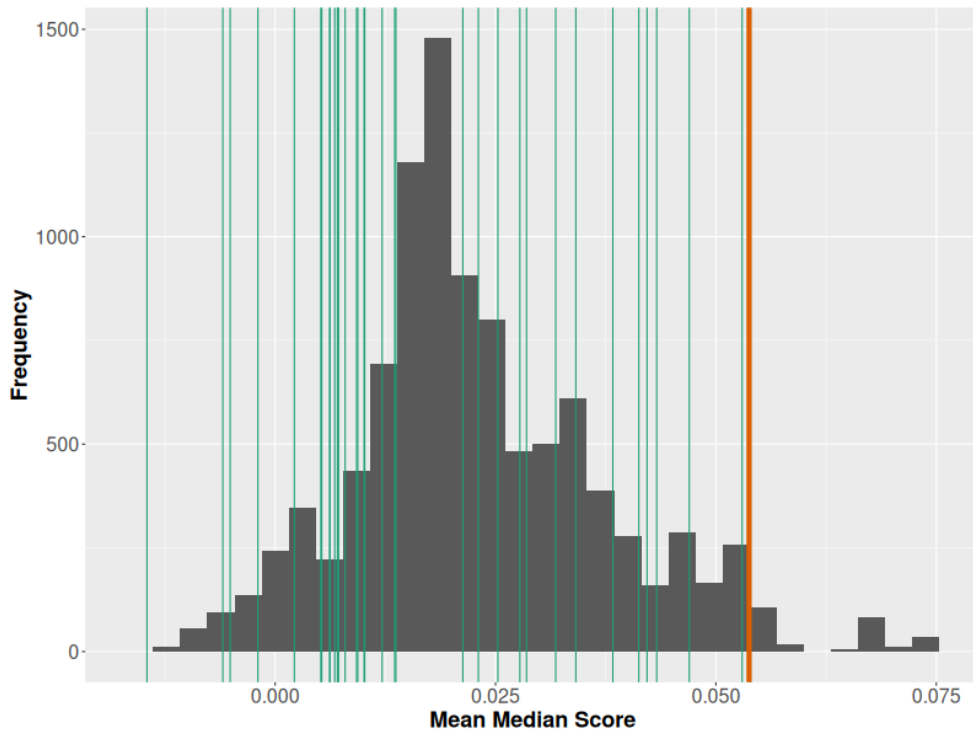
Figure 2 is a histogram displaying the compactness of the simulated plans. In this figure, and all subsequent histograms, the gray bars represent characteristics (compactness, in this case) of a 10,000 plan ensemble generated using Monte Carlo simulation, as explained in the Methods section. In Figure 2, average compactness of citizen-submitted plans are overlaid in vertical blue-green lines, with the “Bipartisan minimal variance plan” highlighted in red. We can see that



*Figure 2: Histogram of average Polsby-Popper compactness of Congressional redistricting plans. Gray bars are plans generated by Monte Carlo simulation. Blue-green lines are individual plans submitted to the public comment portal or to the court in *Carter v. Chapman*. The red line is an example citizen-submitted plan discussed in the text.*

the average district compactness of the highlighted plan is fairly typical of the citizen-submitted plans as a whole, and most citizen plans are more compact than the entire ensemble of simulated plans. While the figure does not differentiate between plans submitted via the public comment portal and those submitted to *Carter v. Chapman*, Table 1 and Table 2 show that the *Carter* submissions are generally more compact than the citizen-submitted plans.

Figure 3 is a histogram of the mean-median scores of the simulated plans. Citizen-submitted plans are overlaid in vertical blue-green lines, with the “Bipartisan Minimal Variance Plan” highlighted in red. The histogram indicates that the highlighted plan is an extreme outlier. The mean-median score is higher than the majority of the simulated plans and *all* other citizen-submitted plans. The citizen-submitted plans and the ensemble cover approximately the same range and on the whole lean towards Republicans (average mean-median score of little over 2%). Arguably, the citizen plans are slightly more balanced, with a cluster of plans with mean-median scores near 0. There is one outlier with a Democratic bias. In comparison, it appears that the “Bipartisan Minimal Variance Plan” mean-median score is relatively high. As discussed before, the use of ensembles helps us answer questions as to whether particular plans are typical or unusual. No single citizen-submitted plan should be selected without analyzing for partisan fairness and comparing with other proposed plans.



*Figure 3: Histogram of mean-median scores of Congressional redistricting plans. Gray bars are plans generated by Monte Carlo simulation. Blue-green lines are individual plans submitted to the public comment portal or to the court in *Carter v. Chapman*. The red line is an example citizen-submitted plan discussed in the text.*

Analysis of Citizen-Submitted Legislative Redistricting Plans

Next we analyze the legislative redistricting plans, beginning with the 50-seat State Senate, followed by the 203-seat House.

Citizens submitted a total of 50 Senate redistricting plans. Table 3 shows the plans with the same set of metrics we calculated for the Congressional plans. The average Polsby-Popper compactness over all plans is 0.3516, maximum population deviation is 4.06%, and the plans produce an average of 26.0 D seats and 24.0 R seats at 52% Democratic vote share. The mean-median score is 0.88%, which translates to 23.9 (out of 50) Democratic seats at 50% vote share. The plans that citizens submitted were all within the 5% population deviation required for Legislative redistricting plans. Several plans are the same (all named “Lehigh...”), and appear to have been submitted by a small group working in concert. Advocating for an opinion as a group is certainly an acceptable part of the democratic process. As our goal is to document citizen participation in the first Pennsylvania redistricting cycle that had such participation to any

Plan	Creator	Mean Compactness	Max Pop Deviation	D Seats	R Seats	Mean-Median
38th PA Senate Plan	RH	0.3353	4.87%	25	25	1.63%
A More Competitive Senate Map	GR	0.4532	4.41%	27	23	-0.18%
A Tweak for the Fair Districts PA Senate Map	RY	0.3713	4.23%	27	23	0.19%
Allentown map	AS	0.3366	4.87%	25	25	1.62%
Balancing Population on the LRC Senate Draft	MW	0.3819	2.07%	26	24	-0.85%
Bucks Co. Senate Districts Communities of Interest	AT	0.2748	16.56%	25	25	1.63%
CCFD proposed Senate map with compact districts	BG	0.3812	2.83%	25	25	2.77%
Christopher Fromme Senate	CF	0.3122	0.41%	26	24	2.26%
Compact, Coherence, and Representative Map	MA	0.4158	2.70%	27	23	1.11%
CORRECTED: Adjustments to PA People's Senate Map	MW	0.3905	3.00%	28	22	-0.32%
Delta Sigma Theta Sorority Senate Map	LM	0.3627	4.87%	25	25	1.65%
Holt Senate Map (Exception 2: Pittsburgh Division)	SP	0.3354	4.87%	25	25	1.61%
Jared Henderson's State Senate Proposal #1	JH	0.3728	1.55%	28	22	-0.48%
Keep State College area intact	DT	0.3359	4.87%	25	25	1.62%
Lehigh County State Senate Map	LH	0.3366	4.87%	25	25	1.62%
Lehigh Senate Maps	EA	0.3366	4.87%	25	25	1.62%
Lehigh Testimony Follow up	MP	0.3366	4.87%	25	25	1.62%
Lehigh Valley redistricting map revised	RS	0.3366	4.87%	25	25	1.62%
Lehigh Valley Revised Map	JS	0.3366	4.87%	25	25	1.62%
LRC Senate Draft - Balanced Metrics and Population	MW	0.3851	2.67%	26	24	0.71%
Map Reflecting Pop Shift w/no Incumbent Primaries	RY	0.3698	3.33%	27	23	0.56%
Math/Science Professors' Exceptions to Senate Plan	SM	0.3643	4.29%	28	22	-0.90%
More compact, more equal pop, no town splits; CCFD	RW	0.4067	5.24%	25	25	1.09%
NE PA Amendments to LRC Senate Preliminary Plan	MW	0.3433	4.77%	25	25	1.61%
Official Submission for PA Senate Districts	M	0.3237	1.53%	29	21	-1.39%
PA 2020 State Senate	CP	0.2396	4.89%	28	22	-0.48%
PA senate districts: no or fewer splits	BK	0.3865	4.77%	25	25	0.82%
PA Senate draft by Kris Rust	KR	0.3446	0.70%	27	23	0.66%
PA Senate Map that is Judicially Enforceable	RW	0.3812	2.83%	25	25	2.77%
PA State Senate Map 2022	GB	0.3625	1.15%	28	22	-1.05%
Pennsylvania Senate 2020	FD	0.3150	5.49%	26	24	0.75%
Pennsylvania State Senate 2020 Verified Fair	JF	0.4229	4.55%	27	23	0.02%
Possible Adjustments to Amanda Holt's Senate Map	MW	0.3681	5.88%	27	23	-0.62%
Possible adjustments to FDPA People's Senate Map	MW	0.3864	3.00%	28	22	-0.86%
Proposed Revision to LRC Senate Preliminary Map -	PR	0.3819	2.07%	26	24	-0.85%
Proposed Revisions of the LRC Senate Map	CK	0.3670	4.07%	27	23	0.38%

Revisions to Proposed Senate Map	JM	0.3361	3.80%	27	23	0.30%
SE PA Revisions to LRC Preliminary Senate Plan	MW	0.3518	4.87%	25	25	1.69%
Senate Districts - Centre County	AW	0.3375	4.87%	25	25	1.64%
Senate Map A, Jesse Stowell	JS	0.3732	2.19%	26	24	0.86%
Senate Maps Lehigh	MM	0.3366	4.87%	25	25	1.62%
Senate Min Deviation + Min County Splits	BF	0.3344	2.12%	29	21	-0.11%
Senate Redistricting map	MR	0.2885	4.92%	25	25	1.51%
Senate: 7 Majority Minority Districts and Purple	RY	0.3704	4.23%	27	23	0.19%
State Sen Min Deviation	BF	0.3239	1.03%	29	21	-0.10%
State Senate	JS	0.3304	4.95%	20	30	4.39%
State Senate Lehigh County	MP	0.3366	4.87%	25	25	1.62%
State Senate Maps	WL	0.3366	4.87%	25	25	1.62%
The Phoenixville Plan for Redistricting	MZ	0.2975	2.78%	26	24	1.40%
Ward take the win	SG	0.3366	4.87%	25	25	1.62%
Citizen Average		0.3516	4.06%	26.0	24.0	0.88%
Ensemble Average		0.2208	4.89%	25.9	24.1	1.23%
Enacted Plan		0.3312	4.30%	26	24	0.68%

Table 3: Pennsylvania Senate Plans Submitted to LRC Public Comment Portal

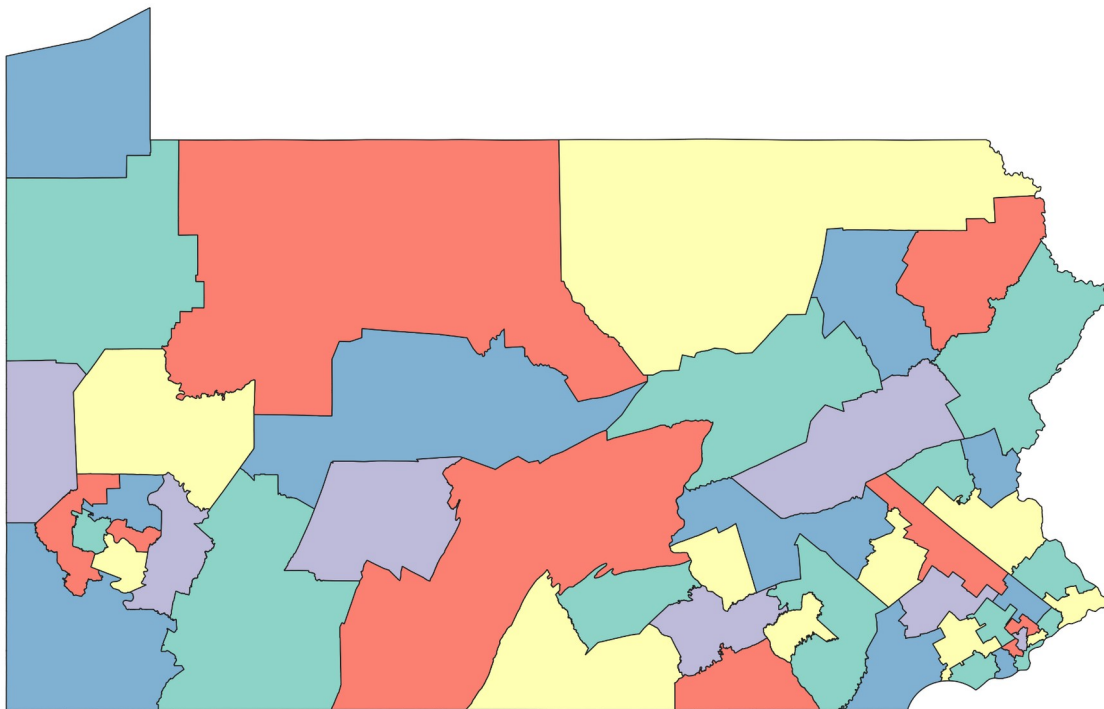


Figure 4: Example citizen-submitted redistricting plan (“Balancing Population”)

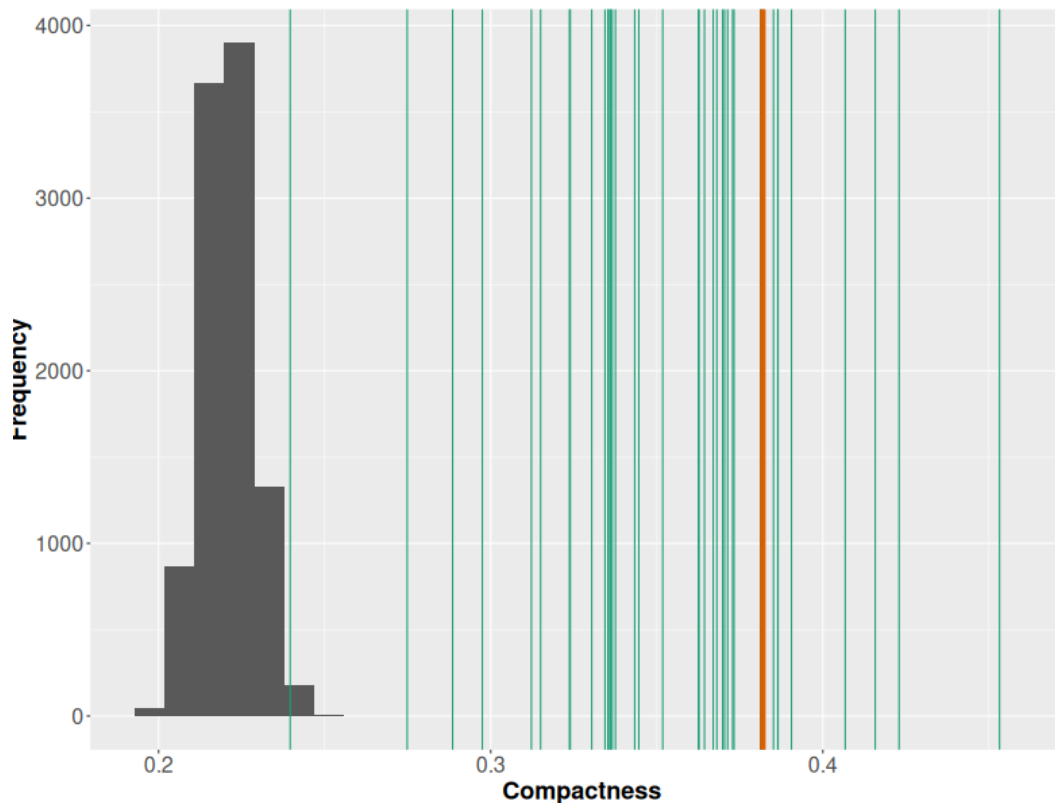


Figure 5: Histogram of average Polsby-Popper compactness of Pennsylvania State Senate redistricting plans. Gray bars are plans generated by Monte Carlo simulation. Blue-green vertical lines are individual plans submitted to the public comment portal. The red line is an example citizen-submitted plan discussed in the text.

significant degree, we overlook issues related to analyzing submissions with duplicate plans. A method for analyzing citizen-submitted plans in the context of growing citizen involvement and possible spamming by advocates, activists, and partisan actors has recently been proposed.³⁸

As we did when analyzing the citizen-submitted Congressional plans, we selected on citizen-submitted legislative plan essentially at random to compare with the other submitted plans and the ensembles. Figure 4 shows the preview of the “Balancing Population” Senate redistricting plan. This map of 50 Senate districts has an average district compactness of 0.3819, a population deviation of 2.07%, and a mean-median score of -0.85%. The estimated partisan outcomes were 26 Democrat seats and 24 Republican seats.

³⁸Ram Gopalan et al., “Selecting Good Redistricting Plans from a Large Pool of Available Plans Using the Efficient Frontier,” *Omega* 124 (April 1, 2024): 103000, <https://doi.org/10.1016/j.omega.2023.103000>.

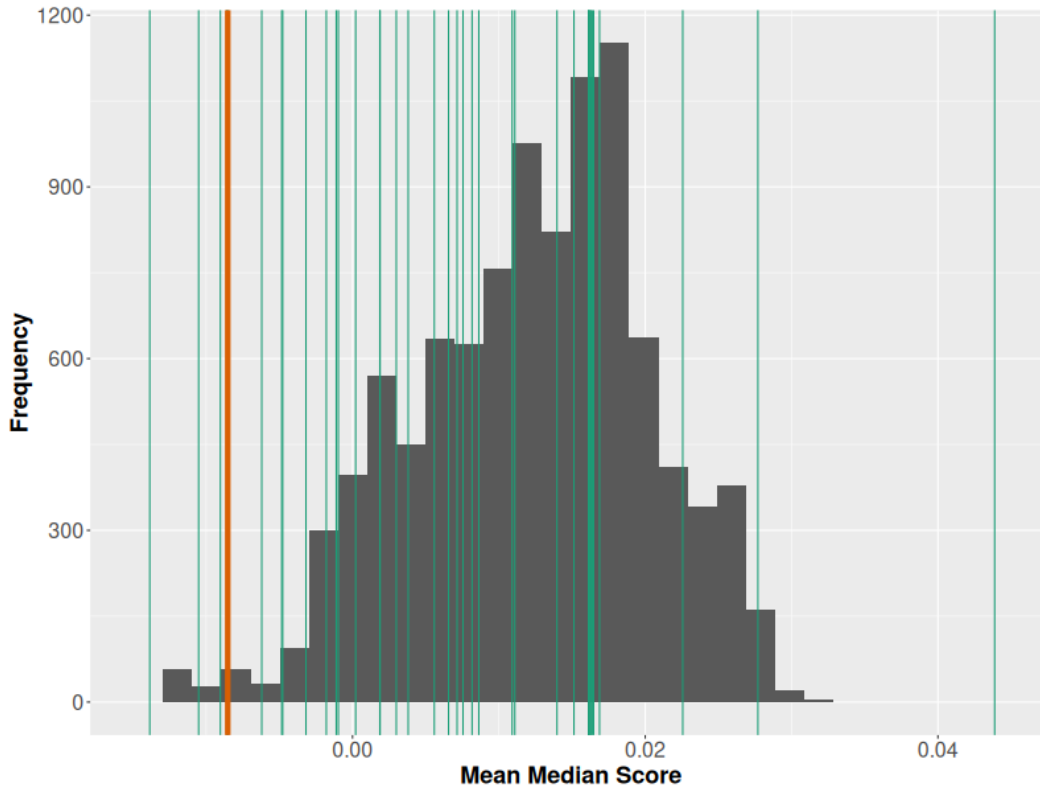


Figure 6: Histogram of mean-median scores of Pennsylvania State Senate redistricting plans. Gray bars are plans generated by Monte Carlo simulation. Blue-green lines are individual plans submitted to the LRC public comment portal. The red line is an example citizen-submitted plan discussed in the text.

Figure 5 shows a histogram of district compactness of the simulated Senate plans. As before, vertical lines indicate citizen-submitted plans, with one citizen plan highlighted in red. We can see that the average district compactness for the “Balancing Population” plan is higher than all simulated plan compactness averages, but is about typical of the citizen-submitted plans.

Figure 6 is a histogram of mean-median scores of the simulated plans. Vertical lines are mean-median scores for citizen-submitted plans, with the “Balancing Population” plan highlighted in red. The citizen plans tend toward the lower end of mean-median scores for the ensemble, while still overlapping considerably with the distribution. The mean-median score of the highlighted plan is significantly lower than the mean-median scores of the vast majority of simulated plans and most of the other citizen-submitted plans. However, this plan is near the average for *absolute* mean-median. It is an outlier in terms of its slight Democratic bias, but there are many plans with a similar bias in the opposite direction (pro-Republican). Overall, these mean-median scores are closer to zero (0.88%) than the Congressional plans (2.36%).

Plan	Creator	Compact- ness	Max Pop Deviation	D Seats	R Seats	Mean- Median
A Fair PA House Map that is Judicially Enforceable	RH	0.3886	4.98%	100	103	2.79%
Adjustments to Preliminary Map	NR	0.3546	10.20%	104	99	1.17%
Concise Westmoreland	MB	0.2851	80.84%	96	107	3.34%
Consolidated LRC Testimony Solutions (All)	PR	0.3674	4.67%	104	99	1.17%
Do Not Split Mechanicsburg Borough	KM	0.3557	4.67%	105	98	0.92%
Lancaster County Metro Area	ED	0.3553	4.67%	105	98	0.92%
Least Splitting and Most Competitive Map	JM	0.3339	2.49%	99	104	2.93%
LRC Testimony Solutions - Consolidated (all)	MW	0.3674	4.67%	104	99	1.17%
LRC Testimony Solutions: Submission 1175	MW	0.3539	4.67%	105	98	0.92%
LRC Testimony Solutions: Submission 578/588 et.al.	MW	0.3574	4.67%	105	98	0.91%
LRC Testimony Solutions: Submission 670/675, et.al	MW	0.3545	4.67%	105	98	0.93%
LRC Testimony Solutions: Submission 775 et.al.	MW	0.3552	4.67%	105	98	0.92%
LRC Testimony Solutions: Submission 777	MW	0.3547	4.67%	105	98	0.92%
LRC Testimony Solutions: Submission 807	MW	0.3528	4.67%	105	98	0.92%
LRC Testimony Solutions: Submission 823/1047/et.al	MW	0.3593	4.67%	105	98	0.93%
LRC Testimony Solutions: Submission 977 et.al.	MW	0.3545	4.67%	105	98	0.92%
LRC Testimony Solutions: Submissions 2766/3017	MW	0.3631	4.67%	105	98	0.91%
Math/Science Professors Exception to House Plan	SM	0.3591	4.48%	111	92	-0.01%
PA House by SRF	SF	0.4050	8.21%	106	97	1.12%
PA house dist. 77, 82, 171 proposed map	BK	0.3535	4.67%	104	99	1.15%
Plan B Modification For Lancaster County	NR	0.3543	8.72%	105	98	0.92%
Plan C Modification for Lancaster County	NR	0.3542	4.67%	104	99	1.16%
Plan D Lancaster County State House	NR	0.3543	4.67%	104	99	1.15%
Plan E Lancaster County Variation	NR	0.3537	4.67%	104	99	1.16%
Preliminary LRC Map - Lancaster 50/96/41 Edit	ar	0.3551	4.67%	105	98	0.91%
Proposed revisions for the LRC House map	CK	0.3737	4.06%	103	100	1.36%
Remedy to Increase Compactness in Luzerne County	JN	0.3544	4.67%	105	98	0.92%
Revision to LRC-House-Preliminary Map	JS	0.3588	4.67%	105	98	1.64%
Revisions to Proposed State House Districts	AY	0.3611	4.67%	105	98	0.91%
Serious Map	N	0.2720	7.56%	96	107	3.72%
State College Adjustment 1	AW	0.3544	4.67%	105	98	0.92%
State House Prioritizing Splitting & Compactness	RC	0.4436	23.55%	101	102	2.46%
Westmoreland United	MK	0.3536	4.67%	105	98	0.92%
Citizen Average		0.3568	7.96%	103.9	99.1	1.31%
Ensemble		0.2385	4.97%	103.1	99.9	2.05%
Enacted Plan		0.3548	4.40%	105	98	1.21%

Table 4: Pennsylvania House Plans Submitted to LRC Public Comment Portal

The final set of plans we analyze are the 33 citizen-submitted plans for the Pennsylvania House of Representatives. Several plans were submitted by the same user and are based on testimony by other users, who often submitted partial plans adjusting a handful of districts in one small part of the state. Table 4 shows all plans with our standard metrics. The average compactness over all plans is 0.3568 and average population deviation is 7.96%. While a handful of the plans had very large population deviations, most fell just within the 5% cutoff required for legislative redistricting plans. The average mean-median score is 1.31%, which translates to 108.1 Republican seats and 94.9 Democratic seats at equal two-party vote. The average citizen-submitted plans were more compact and had greater partisan bias (higher mean-median scores) than the enacted plan.

Figure 7 is a map of the “Plan E Lancaster County” redistricting plan showing 203 House districts. This redistricting plan has a compactness score of 0.3537, percent population deviation of 4.67%, and a mean-median score of 1.16%, which would produce about 96 Democratic seats and 107 Republican seats at a 50/50 two party vote.

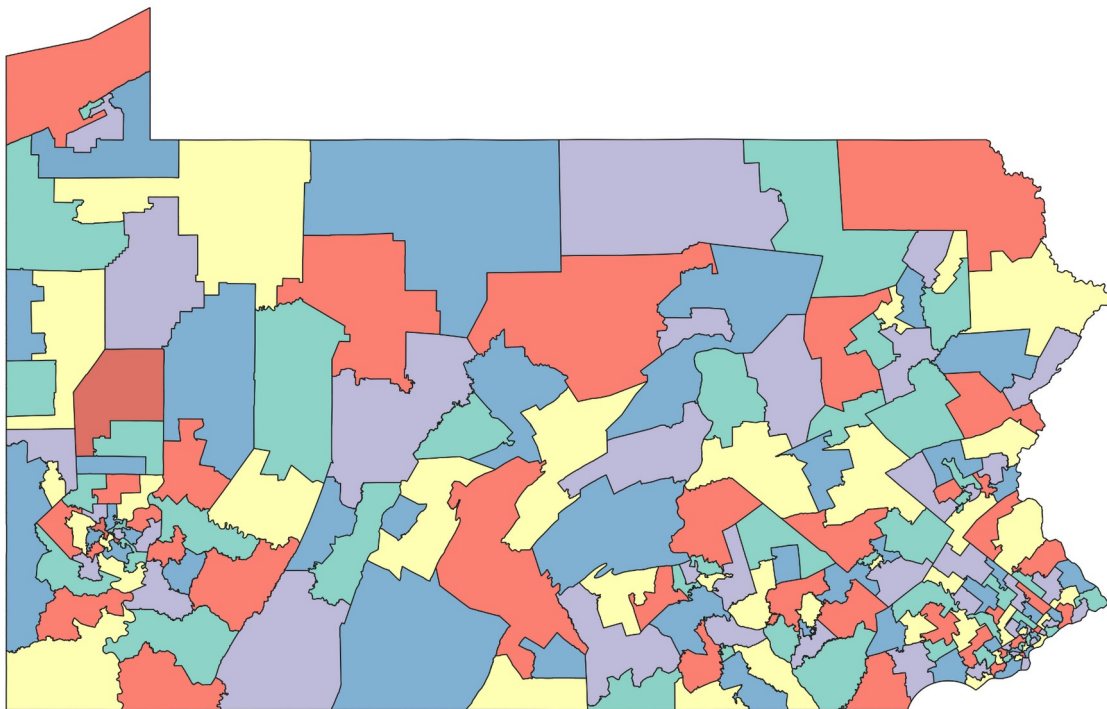


Figure 7: Example citizen-submitted plan (“Plan E Lancaster County”)

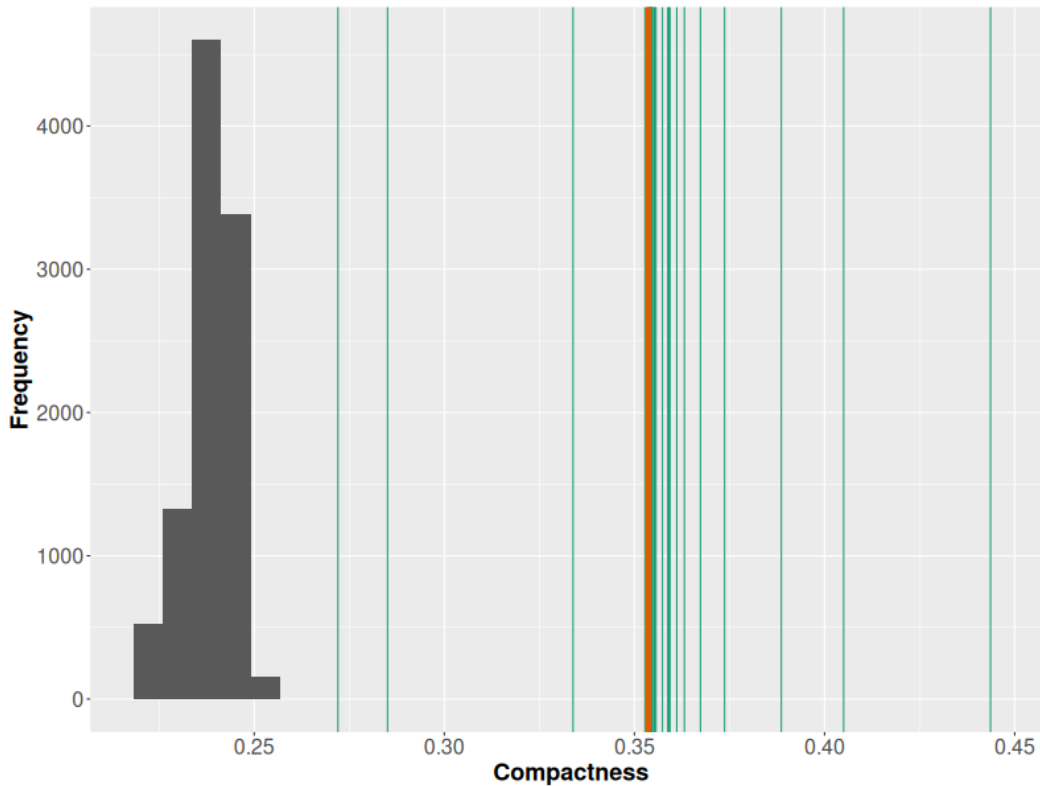


Figure 8: Histogram of average Polsby-Popper compactness of Pennsylvania House of Representatives redistricting plans. Gray bars are plans generated by Monte Carlo simulation. Blue-green lines are individual plans submitted to the LRC public comment portal. The red line is an example citizen-submitted plan discussed in the text.

Figure 8 is a histogram displaying the compactness of the simulated plans. The vertical blue-green lines show average district compactness for the citizen-submitted plans, with “Plan E Lancaster County” highlighted in red. The citizen-submitted plans are *all* more compact than *all* plans generated by simulation.

Figure 9 is a histogram of mean-median scores of the simulated plans. The vertical blue-green lines show citizen-submitted plans, with “Plan E Lancaster County” highlighted in red. The mean-median scores for the citizen-submitted plans show greater diversity than those of the ensemble. The mean-median scores for the ensemble and all but one of the citizen-submitted plans are positive, indicating varying degrees of Republican bias. While a few citizen-submitted plans show more Republican bias than the ensemble, a cluster of citizen-submitted plans have biases of just under 1%, at the lower end of the ensemble distribution. Arguably, the citizen plans as a whole perform better than the ensemble in terms of partisan fairness, though with greater variability.

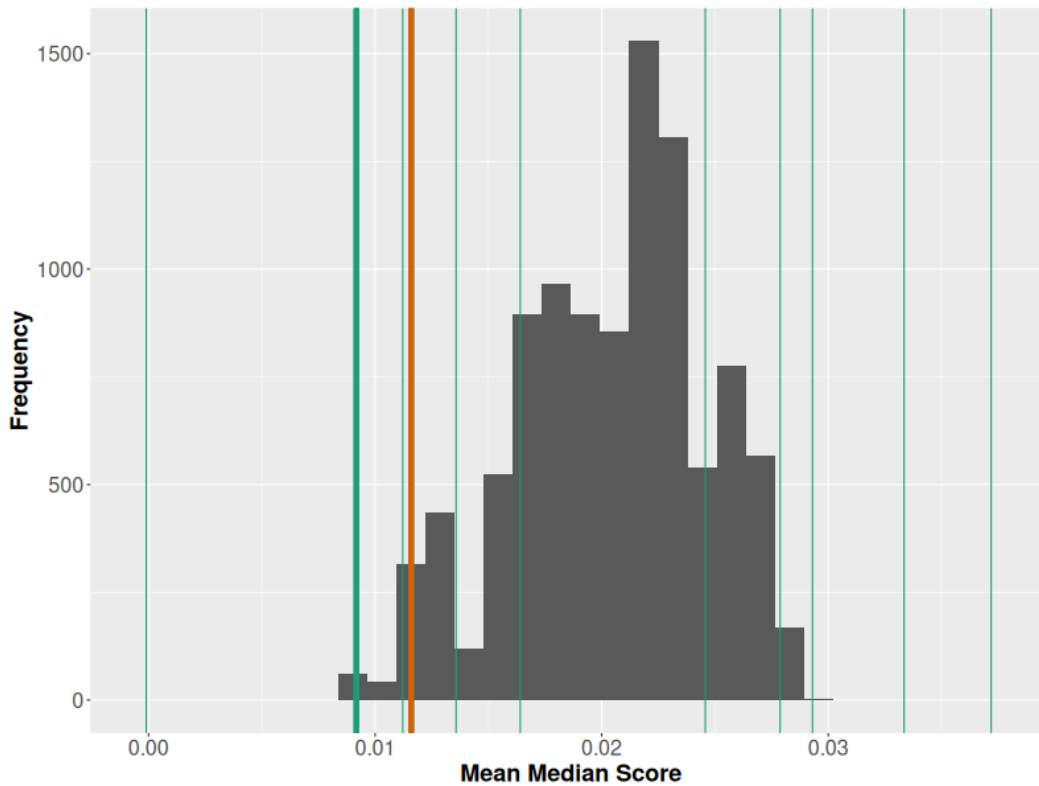


Figure 9: Histogram of mean-median scores of Pennsylvania House of Representatives redistricting plans. Gray bars are plans generated by Monte Carlo simulation. Blue-green lines are individual plans submitted to the LRC public comment portal. The red line is an example citizen-submitted plan discussed in the text.

Discussion

For this project we gathered all known proposed redistricting plans for both Congressional and legislative redistricting submitted by citizens and Congressional plans submitted by participants in *Chapman v. Carter*. We believe this to be the only such repository of Pennsylvania’s citizen-submitted redistricting plans formatted for easy analysis by future researchers using standard redistricting software. In the process, we found Congressional plans incorrectly submitted to the LRC, saving future researchers considerable effort finding plans across multiple public platforms.

We used software developed by leading redistricting researchers to generate ensembles using Monte Carlo simulation and to calculate metrics on a limited set of redistricting criteria for all submitted plans. We ran the Monte Carlo simulation on standard desktop computers, and used a relatively small run length of 10,000 simulations. Future research would benefit from longer run length and fine-tuning of the Monte Carlo simulation parameters. Nonetheless, we are able

to compare the plans with each other and with these ensembles. We discussed some of these results above, and here make some remarks on citizen-submitted plans across all three redistrictings.

Population equality standards are different for legislative plans, where districts should be within 5% of the ideal population, and Congressional plans, where redistricters often strive for 1 person deviation. It is interesting to note that the Congressional plans submitted to the court in *Carter v. Chapman*, which had a strong likelihood of actual selection as the enacted redistricting plan, hewed closely to the standard of population equality. The one exception was a plan submitted by an advocate (Khalif Ali) who has argued strongly for the community of interest standard, and was perhaps making a point about the tradeoffs of an overly strict focus on population equality. The legislative plans, on the other hand, are largely clustered just under the 5% cutoff. A handful of legislative plans strove for smaller deviations, and a small number seemed to ignore it entirely. This would seem to indicate that redistricters are treating the 5% as a hard constraint, and once they satisfy it, they turn their attention to improving other criteria such as compactness or partisan bias.

Mean-median score differences, an indicator of partisan bias, were on average lower for the legislative plans (0.88% for the Senate and 1.31% for the House) than for the Congressional public comment plans (2.36%). As discussed previously, the Congressional redistricting web portal drew very few submissions. The higher mean-median average may be a result of a few outliers in a smaller set of Congressional plans. Greater publicization of opportunities for citizen comment is a good in and of itself, and may also yield a set of plans with lower partisan bias on average. Average mean-median differences were the lowest (0.79%) for the 14 plans submitted by interested parties to *Carter v. Chapman*, indicative of the care that petitioners and *amici* took in crafting plans which stood a reasonable chance of being selected by the court as the enacted Congressional plan. The averages for the legislative and Congressional plans are all positive, indicating varying degrees of Republican bias. This positive tilt is consistent with the widely held view that Democratic “self-packing” in urban areas tends to produce Republican-leaning plans. In response, some analysts have argued for an “anti-gerrymander” to overcome this political geography by producing plans that come closer to representing the statewide electorate.³⁹ The plans in this report show that this can be done, as there are plans that have close to zero bias.

Finally, we note that for the two metrics we plotted above, compactness and mean-median score, the citizen-submitted plans perform significantly better on compactness and are about equivalent or slightly better on partisan bias (mean-median) than the ensembles. In some ways this is not surprising. The basic Monte Carlo process produces plans randomly, and it would be odd if it produced plans matching the distribution of plans meeting the diverse goals of human designers. The redist software can be parameterized to make it produce plans that tend toward specified goals, but the only tuning we did for this analysis was to set a parameter to encourage

³⁹John F. Nagle, “What Criteria Should Be Used for Redistricting Reform?,” *Election Law Journal: Rules, Politics, and Policy* 18, no. 1 (2019): 63–77.

not splitting counties. The point that we want to make here is that a fairly small number of human plans, generated by citizens with competing interests, can give us a set of plans that are quite good on these legally required criteria. The purpose of the Monte Carlo simulation is not optimization, i.e., producing a “best” plan, but understanding the distribution of *possible* plans in order to reveal outlier plans. While some citizen-created plans show up as outliers (likely gerrymanders), most citizen-created plans seem to have been created by conscientious actors interested in creating plans that produce fair representation and meet legal criteria to be enacted. We believe that greater citizen involvement will be a boon to fair redistricting. Further research could involve generating longer Monte Carlo runs while tuning the parameters, and exploring tradeoffs among the criteria in the citizen-generated plans.

Recommendations

This report offers a technical approach to the analysis of citizen-generated redistricting plans. More broadly, it underscores the value of citizen involvement. The Legislative Redistricting Commission (LRC) in 2021 and 2022 touted its use of an open channel for citizen comments and recommendations. Indeed, LRC chair Mark Nordenberg, in his speech during the last open meeting of the Commission on February 4, 2022, highlighted this fact, noting early in his remarks that they “... created a website portal to receive citizen comments, which attracted 5,856 submissions. We also received 155 submissions that came to us through mail or email, for a grand total of more than 6,000 submissions. All of them were read by at least two members of the Commission team, and they were organized to make them accessible to us as we moved forward with our work.”⁴⁰

Comments in the final report published a month later emphasized the Commission’s commitment to using public comments: “The LRC’s Final Plan, adopted by a 4 to 1 vote of the Commission, is the product of exhaustive efforts by the Commission members and their teams, unprecedented levels of contact with and feedback from the public, and a deep reservoir of invaluable expert advice.”⁴¹

The LRC created an effective system for public participation through its online platform and in-person hearings. This stands in sharp contrast to the more limited options available during the Congressional redistricting process. The LRC’s website accepted plans in common file formats and made all submissions publicly available. This accessibility resulted in numerous citizen submissions, providing substantial data for analyzing both state Senate and House redistricting plans.

⁴⁰Chairman Mark A. Nordenberg, opening remarks at LRC meeting, February 4, 2022.

<https://www.redistricting.state.pa.us/resources/Press/2022-02-04%20Chairmans%20Statement.pdf>

⁴¹Report of Mark A Nordenberg Chair of the 2021 Pennsylvania Legislative Reapportionment Commission Regarding the Commission’s Final Plan, March 4, 2022, page 68.

<https://www.redistricting.state.pa.us/resources/Press/2022-03-04%20Report%20Chair%20of%202021%20LRC%20Final%20Plan.pdf>

The legislature, responsible for Congressional redistricting, also created a public comment portal, but as discussed previously, the portal was difficult to use (even for experienced participants) and not well-publicized. Moreover, the domain registration was allowed to lapse after the redistricting was completed. This may be taken as revealing the legislature's lack of interest in citizen input to Congressional redistricting. For the 2031 redistricting, we call on the legislature (or, if there are any changes to Pennsylvania's redistricting process, whatever body is responsible for Congressional redistricting), to follow the example set by the LRC and create an accessible, well-publicized public comment portal, and allow plans to be submitted using free web-based tools such as Dave's Redistricting App or DistrictBuilder.

This study shows that citizen input provides valuable insight into community preferences and helps quantify which map features matter most to voters. Public participation in redistricting serves multiple purposes. It allows redistricting bodies to demonstrate transparency and engagement with voters. More importantly, public comments often highlight local concerns that mapmakers might otherwise miss. When redistricting bodies address these concerns, the resulting maps typically receive broader public support.

Organizations like CCFD play an important role in analyzing citizen preferences and improving judicial oversight of the redistricting process. This study shows that randomly generated district maps often produce different statistical outcomes than do citizen-designed maps. These differences reveal specific citizen preferences that wouldn't appear in computer-generated alternatives. For example, citizens consistently drew more compact districts than those produced by random map generation. On partisan bias (mean-median scores), the citizen plans on average performed marginally better than the ensembles, particularly for the state Senate districts, but covered roughly the same range of low to high bias as the randomly-generated ones. This may indicate less concern about variations in partisan bias, or merely that the ensembles do a reasonable job of creating unbiased redistricting plans, and citizens usually avoid creating extreme outliers compared with the ensembles. Future research by groups like CCFD will help better characterize and document revealed citizen preferences.

One specific issue requiring attention is the different treatment of prison populations in state legislative versus congressional redistricting. In the 2021 redistricting cycle, legislative districts counted prisoners at their last known address, while Congressional maps counted them at their prison location. This inconsistency led to legal challenges in 2022, with some legislators arguing that the LRC approach violated constitutional requirements. Resolving such discrepancies through clear legislation will improve the 2031 redistricting process.

The redistricting process will continue to evolve through research findings, court decisions, and electoral outcomes. These developments will likely lead to new legislation that better defines redistricting criteria and procedures. Pennsylvania has already seen proposed bills to create and structure an independent redistricting commission.⁴² These proposals have generated

⁴²[PA Senate Bill 131 Cosponsorship Memo 20250117](#), [PA House Bill 31 Cosponsorship Memo 20250128](#)

substantial discussion among legislators and citizens, leading to ongoing refinements.

The combination of technical research, legislative debate and citizen initiatives will continue to advance the institutions of redistricting. We hope that these pressures will lead to improvements in redistricting transparency, neutrality, and fair representation.

About Concerned Citizens for Democracy

Concerned Citizens for Democracy (CCFD) is a 501(c)(3) nonpartisan Pennsylvania Nonprofit Association composed of lawyers, mathematicians, engineers, geographers, GIS analysts and other activists dedicated to ending partisan gerrymandering, focusing on Pennsylvania. Our mission is to promote fairly drawn electoral districts through research and development of rigorously applied neutral design criteria that legislatures and courts understand and can enforce.

About This Report

This project was initiated by Anya Dougherty as a capstone project in Temple University's Professional Science Master's in Geographic Information Systems under the supervision of Temple professor and CCFD member Lee Hachadoorian. Anya met regularly with CCFD's Data Science Team including Lee and CCFD Managers Anne Hanna and Bob Hess, and CCFD member Matt Munsey. John Nagle joined CCFD as a Manager and member of the Data Science Team as the report was nearing completion, and provided significant additional analysis and methodological critique in a short period of time.

Anya gathered the plans analyzed in this report from disparate sources as detailed above, converted them to block/precinct assignment file formats, wrote R code used for the analysis, and completed a draft of this report. Lee reviewed the R code, further contributed to the analysis, and did additional work converting submissions to analyzable format. The Data Science Team as a whole served as advisors on technical and methodological issues, and decided collectively how to fix plans with minor errors so as to be able to include them in the analysis. Lee served as editor for the final report with additional writing by Lee, Anne, Bob, and John. The final report was reviewed and approved by CCFD's Managers.

The underlying data and code supporting this report is available in three online repositories:

- Plans: <https://github.com/ccfdpa/pa-citizen-redistricting-plans-2020>
- Analysis scripts: <https://github.com/ccfdpa/ccfd-citizen-redistricting-plan-analysis>
- Replication Data: <https://github.com/ccfdpa/ccfd-citizen-redistricting-plan-replication-data> (stored separately because of size, can be generated by the analysis scripts)

References

- “August 24th - Legislative Reapportionment Commission Approves Resolution Regarding Prisoner Data Reallocation,” August 24, 2021. <https://www.redistricting.state.pa.us/commission/article/1070>.
- Baer, Max. “Majority Opinion Chief Justice Baer,” March 9, 2022. [https://vhdsfh2oms2wcnsvk7sdv3so.blob.core.windows.net/thearp-media/documents/Majority Opinion - C.J. Baer 3.9.22.pdf](https://vhdsfh2oms2wcnsvk7sdv3so.blob.core.windows.net/thearp-media/documents/Majority%20Opinion%20-%20C.J.%20Baer%203.9.22.pdf).
- . “Re: Pennsylvania Legislative Reapportionment Commission,” May 3, 2021. <https://www.redistricting.state.pa.us/resources/press/2021-05-03%20Supreme%20Court%20appoints%20Mark%20Nordenberg.pdf>.
- “Calculates Maximum Deviation from Population Parity — Redist.Parity.” Accessed August 2, 2024. <https://alarm-redist.org/redist/reference/redist.parity.html>.
- Carter, Carol Ann, Monica Parrilla, Rebecca Poyourow, William Tung, Burt Siegel, Susan Cassanelli, Lynn Wachman, et al. “Petition for Review,” December 17, 2021.
- Chen, Jowei, and Jonathan Rodden. “Unintentional Gerrymandering: Political Geography and Electoral Bias in Legislatures.” *Quarterly Journal of Political Science* 8, no. 3 (June 27, 2013): 239–69. <https://doi.org/10.1561/100.00012033>.
- DeFord, Daryl, and Duchin, Moon. “Random Walks and the Universe of Districting Plans.” In *Political Geometry*, edited by Moon Duchin, Ari Nieh, and Olivia Walch, 341–81. Birkhäuser Basel, 2020. <https://moggg.org/publications/political-geometry/17-DefordDuchin.pdf>.
- Engstrom, Erik J. *Partisan Gerrymandering and the Construction of American Democracy*. Legislative Politics & Policy Making. Ann Arbor, MI: University of Michigan Press, 2016.
- Gopalan, Ram, Lee Hachadoorian, Steven O. Kimbrough, and Frederic H. Murphy. “Selecting Good Redistricting Plans from a Large Pool of Available Plans Using the Efficient Frontier.” *Omega* 124 (April 1, 2024): 103000. <https://doi.org/10.1016/j.omega.2023.103000>.
- Hanna, Anne. “Personal Communication,” November 10, 2024.
- Huangpu, Kate. “Congressional Map Picked by Pennsylvania Supreme Court Unlikely to Dramatically Alter Partisan Balance,” February 23, 2022. <https://www.spotlightpa.org/news/2022/02/pennsylvania-redistricting-congressional-map-supreme-court-pick/>.
- Huangpu, Kate, and Angela Coulombis. “Democrats Could Make Sizeable Gains in Pennsylvania Legislature under Proposed New Maps,” December 16, 2021. <https://www.spotlightpa.org/news/2021/12/pennsylvania-redistricting-state-house-senate-maps/>.
- Kenny, Christopher T., Cory McCartan, Benjamin Fifield, and Kosuke Imai. “Redist: Simulation Methods for Legislative Redistricting.” R, 2022. <https://alarm-redist.org/redist/>.
- “League of Women Voters of Pennsylvania v. Commonwealth of Pennsylvania.” Brennan Center for Justice, October 29, 2018. <https://www.brennancenter.org/our-work/court-cases/league-women-voters-pennsylvania-v-commonwealth-pennsylvania>.
- Levitt, Justin, and Doug Spencer. “Pennsylvania: State Summary.” All About Redistricting. Accessed September 18, 2024. <https://redistricting.ils.edu/state/pennsylvania/>.
- . “Who Draws the Lines?” All About Redistricting. Accessed September 18, 2024. <https://redistricting.ils.edu/redistricting-101/who-draws-the-lines/>.

- McGann, Anthony J., Charles Anthony Smith, Michael Latner, and Alex Keena. *Gerrymandering in America: The House of Representatives, the Supreme Court, and the Future of Popular Sovereignty*. New York, NY: Cambridge University Press, 2016.
- Murphy, Jan. "House Panel Extends Deadline for Proposed Congressional Map Submissions." *PennLive*, December 3, 2021. <https://www.pennlive.com/news/2021/12/house-panel-extends-deadline-for-proposed-congressional-map-submissions.html>.
- Nagle, John F. "What Criteria Should Be Used for Redistricting Reform?" *Election Law Journal: Rules, Politics, and Policy* 18, no. 1 (2019): 63–77.
- Nordenberg, Mark. "Meeting of the Pennsylvania Legislative Reapportionment Commission Approval of a Final Plan," February 4, 2022. <https://www.redistricting.state.pa.us/resources/Press/2022-02-04%20Chairmans%20Statement.pdf>.
- Pennsylvania Redistricting. "Deadline for Public Comment," January 15, 2022. <https://www.redistricting.state.pa.us/commission/article/1094>.
- Pennsylvania Redistricting. "Hearings," n.d. <https://www.redistricting.state.pa.us/commission/hearings>.
- Pennsylvania Redistricting. "LRC Adopts 2021 Final Plans," February 4, 2022. <https://www.redistricting.state.pa.us/commission/article/1096>.
- Pennsylvania Senate Democrats. "Pennsylvania Redistricting." Accessed July 4, 2024. <https://pasenate.com/redistricting/>.
- PGP. "Redistricting Report Card - Pennsylvania 2022 Final State Senate Map - Enacted." *Gerrymandering Project*, December 16, 2023. <https://gerrymander.princeton.edu/redistricting-report-card/?planId=recNBn0tcg8xEtfv2>.
- PlanScore. "Mean-Median Difference." Accessed August 3, 2024. <https://planscore.org/metrics/meanmedian/>.
- PlanScore. "PlanScore: Pennsylvania." PlanScore. Accessed January 27, 2025. <https://planscore.org/pennsylvania/#!2022-plan-statehouse-eg>.
- Polsby, Daniel D., and Robert D. Popper. "The Third Criterion: Compactness as a Procedural Safeguard against Partisan Gerrymandering." *Yale Law & Policy Review* 9, no. 2 (1991): 301–53.
- "Redistricting Cases 464 MD 2021 and 465 MD 2021 | Cases of Public Interest | News & Statistics | Unified Judicial System of Pennsylvania." Accessed July 4, 2024. <https://www.pacourts.us/news-and-statistics/cases-of-public-interest/redistricting-cases-464-md-2021-and-465-md-2021>.
- "Redistricting Report Card - Pennsylvania 2022 Final Congressional Map - Enacted." Accessed August 2, 2024. <https://gerrymander.princeton.edu/redistricting-report-card/?planId=recT95YHHudtpR3Fc>.
- Team, Voting and Election Science. "2020 Precinct-Level Election Results." *Harvard Dataverse*, October 11, 2024. <https://doi.org/10.7910/DVN/K7760H>.
- The American Redistricting Project*. "Carter v. Chapman." October 3, 2022. <https://thearp.org/litigation/carter-v-chapman/>.
- The Public Interest Law Center. "Taking on Prison Gerrymandering, Formerly Incarcerated Voters and the NAACP-PA File an Amicus Brief Supporting PA State House and Senate Maps," March 11, 2022. <https://pubintlaw.org/cases-and-projects/taking-on-prison-gerrymandering-formerly-incarcerated-voters-and-the-naacp-pa-file-an-amicus-brief-supporting-pa-state-house-and-senate-maps/>.
- Vieth v. Jubelirer, Cornell Law School: Legal Information Institute (U. S. Supreme Court 2004), <https://www.law.cornell.edu/supct/html/02-1580.ZS.html>.