2021 Missouri Redistricting Analysis for the League of Women Voters

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This research analysis was conducted as part of the Institute for Computational Redistricting (ICOR) at the University of Illinois at Urbana-Champaign. This activity was conducted in a non-partisan manner, with any political descriptors used reflecting the results of the quantitative analysis, not the opinions of the researchers nor ICOR.

Contents

Executive Summary

The Institute for Computational Redistricting (http://redistricting.cs.illinois.edu) is a research group at the University of Illinois at Urbana-Champaign. Under the direction of Dr. Sheldon H. Jacobson (http://shj.cs.illinois.edu) and Dr. Douglas M. King, the group focuses on computational methods for redistricting to provide transparency within the redistricting process. In January 2021, the Missouri League of Women Voters (MO-LWV) contacted the group to prepare U.S. congressional district plans for Missouri, and state legislative district plans (state senate/house) that satisfy the new redistricting criteria amended to the Missouri Constitution in 2020. The new criteria for state legislative plans introduces a maximum allowed percent deviation for district populations, and prioritizes compactness and the preservation of political subdivisions over partisan fairness requirements. For congressional plans, Missouri only requires contiguous and compact districts, in addition to the requirements from the U.S. Constitution. The goals of this analysis are to examine the physical and partisan characteristics of plans that satisfy constitutional requirements, and to examine the interplay between legal requirements and partisan fairness.

For state legislative district plans, we explore questions such as how many counties (i.e., a type of political subdivision) can be kept intact under the new population requirement, how many seats can each party expect to win, and how much can partisan fairness be improved (beyond any constitutionally required thresholds). For example, the new population requirement affects how many state legislative districts can fit inside highly populated counties. Also, prioritizing compactness and preserving political subdivisions over partisan fairness allows Democrats to be packed into urban districts.

The Missouri Constitution has fewer requirements for congressional district plans than for state legislative district plans. Therefore, in contrast to the state legislative plans, there are many ways to draw the congressional district boundaries that satisfy constitutional requirements; some ways exhibit good partisan fairness, and others exhibit poor partisan fairness. It is also important to create these district plans by transparent means; with no insight into how a plan was constructed, it is not clear whether undesirable qualities (e.g., packing and cracking, non-competitive districts) are due to gerrymandering or are a natural result of constitutional requirements and political geography.

We use an optimization algorithm to create a collection of district plans (two state senate, two state house, and eight congressional) that satisfy legal requirements and prioritize different fairness objectives (e.g., compactness, the Efficiency Gap). Although compactness is prioritized in the Missouri Constitution (for both state legislative and congressional plans), focusing on additional aspects of fairness can illustrate the range of partisan outcomes that is possible for Missouri's legal requirements and political geography. Optimization algorithms promote transparency in each step of the districting process, since they have clearly defined objectives, constraints, and parameters. A discussion accompanies the collection of district plans, including the advantages and disadvantages of each plan, and how legal requirements and political geography impact the redistricting process.

Ultimately, the results show that Missouri's unique political geography, combined with the constitutional requirements, gives Republicans an inherent advantage. For example, district plans created to solely prioritize compactness tend to pack/crack Democratic votes, since Democrats are concentrated in a few urban centers with fewer voters throughout the rest of the state. Hence, many Democratic votes are considered wasted, since packed districts have many more votes than are needed to win their elections and cracked districts are lost by small margins. In contrast, Republicans are more evenly distributed throughout the state, and hence tend to waste fewer votes than Democrats do and are better able to translate their votes into seats. Preserving political subdivisions (e.g., county lines), as required by the Missouri Constitution for state legislative district plans, exacerbates this problem. **The state legislative plans must satisfy a constitutionally required threshold for partisan fairness (related to the Efficiency Gap), but plans that solely prioritize compactness can satisfy this threshold while still wasting many votes.**

We ran experiments to improve partisan fairness in state legislative plans (as measured by various voting-based metrics), but were unable to make improvement while maintaining compact districts and preserving county lines. **Hence, Missouri's constitutional requirements severely limit the options available for legally acceptable state senate/house district plans.**

In contrast, partisan fairness can be substantially improved in congressional plans while maintaining compactness and a majority-minority district. We present compact congressional plans that also have good Efficiency Gap values, good Partisan Asymmetry values, or four competitive districts. In particular, the congressional plans that prioritize the Efficiency Gap ***and*** compactness have compactness scores comparable to plans that ***solely*** prioritize compactness, but their Efficiency Gap values have improved (i.e., decreased) by more than 15%.

1. Introduction

Missouri has changed its state legislative redistricting requirements twice since the last redistricting cycle in 2011 (Mo. Const. art. III, §3). While the 2018 redistricting amendment prioritized partisan fairness (i.e., the Efficiency Gap), the 2020 redistricting amendment prioritizes compactness and the preservation of political subdivisions (e.g., counties). The 2020 amendment also defines a maximum allowed percent deviation for district populations. For congressional redistricting, Missouri requires contiguous and compact districts, in addition to the requirements from the U.S. Constitution (Mo. Const. art. III, §45). The Missouri League of Women Voters (MO-LWV) contacted the Institute for Computational Redistricting (ICOR) to construct state legislative and congressional district plans that satisfy constitutional requirements.

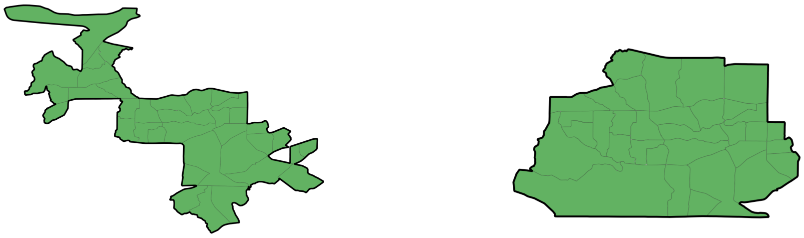
This report provides the MO-LWV with a collection of two state senate, two state house, and eight congressional district plans. The plans are constructed with an optimization algorithm to promote transparency in the districting process. To assess the preservation of political subdivisions for the state legislative plans, we examine how many districts can fit inside highly populated counties under the new population requirement, and how many counties must be split. For the congressional plans, we maintain a majority-minority district. To examine the interplay between redistricting requirements and partisan fairness, some plans presented in this report prioritize compactness, while others prioritize partisan aspects of fairness (e.g., the Efficiency Gap). Although the Missouri Constitution prioritizes compactness, focusing on multiple aspects of fairness allows one to examine how constitutional requirements and political geography affect the level of political fairness achievable for Missouri. Each plan is scored with various fairness metrics, and the advantages and disadvantages between plans are discussed. The results show that state legislative district plans that satisfy constitutional requirements have an inherent Republican advantage, likely attributable to the political geography of the state. For congressional district plans, the results show that compactness ***and*** good political fairness are achievable for Missouri.

This report is organized as follows. Section 2 describes the fairness metrics used to evaluate district plans. Section 3 gives an overview of the optimization method used to construct the plans that optimize these fairness metrics. Section 4 outlines Missouri's redistricting requirements, data, and geography. Lastly, Section 5 presents the district plans and Section 6 discusses and compares their partisan characteristics.

2. Fairness Metrics

In the context of redistricting, "fairness" can be interpreted in a number of ways. Sometimes fairness focuses on political parties; for example, a district plan could be considered fair if neither party is *packed* and *cracked* (i.e., concentrated in a few districts where it wins by overwhelming margins, then diluted among the remaining districts). Fairness can also mean reasonably shaped districts, or competitive districts. Throughout this report, we refer to metrics that use voting data as *partisan fairness metrics*; compactness is the only fairness metric considered in this report that is not a partisan fairness metric. Each district plan presented in this report is evaluated with various metrics that quantify these common aspects of fairness. This section gives an overview of each metric.

- *Compactness:* A district is compact if it has a simple shape (such as a circle or square, as in Figure 1b), as opposed to a convoluted shape (as in Figure 1a). Simple shapes are preferred, since convoluted district shapes can be a result of intentional boundary manipulation for political gain. For example, the salamander-shaped Massachusetts district that inspired the term *gerrymander* was constructed to pack Federalist voters (Massachusetts Historical Society). There are several ways one could quantify district compactness (Young 1988); we choose to measure compactness as the sum of all district perimeters (reported in miles). We exclude perimeter segments that coincide with Missouri's state boundary, since the state boundary will always overlap with district perimeter segments for any district plan. A district with an irregular shape (as in Figure 1a) has a larger perimeter than a district with a simpler shape (as in Figure 1b), which means that smaller values of this metric indicate more compact districts.



(a) A non-compact district with a perimeter of 197 miles

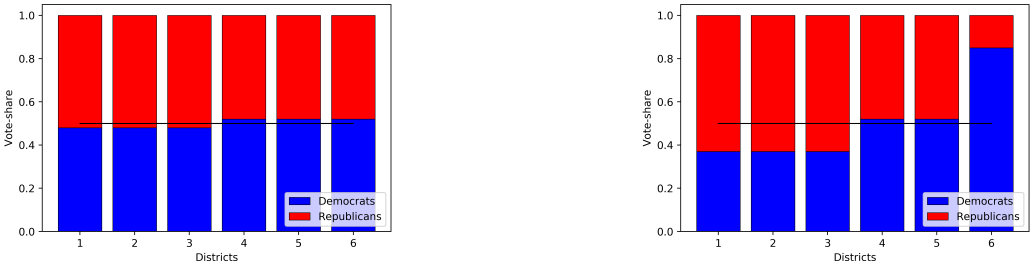
(b) A compact district with a perimeter of 94 miles

Figure 1 **Two examples of district shapes (for roughly the same location and district population). Figure 1a shows a non-compact district and Figure 1b shows a compact district.**

- *Efficiency Gap:* The Efficiency Gap aims to quantify packing and cracking. A packed party wastes votes because it wins districts by overwhelming margins; a cracked party wastes votes because it narrowly loses many districts. Hence, "wasted votes" are votes cast for a district's losing party, or votes cast for a district's winning party in excess of the 50% needed to win the election. The Efficiency Gap measures the difference in wasted votes between both parties and reports this difference as a percentage of the total votes cast for these two parties (Stephanopoulos and McGhee 2015). Smaller values of this metric indicate that both parties waste a similar number of votes, which means both parties are packed and cracked to a similar degree. For example, the vote-share scenario in Figure 2a has a large Efficiency Gap because Republicans are cracked, and therefore waste many votes; the vote-share scenarios in Figures 2b, 2c, and 2d have small Efficiency Gap values, because both parties waste votes equally.
- *Shifted Efficiency Gap:* The Shifted Efficiency Gap (referred to as "Competitiveness" in the Missouri Constitution (Mo. Const. art. III, §3)) examines how the Efficiency Gap changes with small shifts in voter preferences. The Efficiency Gap relies on voting data from previous elections, and voting behavior might change in future elections. Consider a scenario with multiple very competitive districts (as in Figure 2c); Democrats might narrowly win all the districts in one election, then narrowly lose them all in the next election. Democrats waste many more votes for the latter outcome than the former, even though the change in voter preference is small. To capture the robustness of a district plan, the Shifted Efficiency Gap calculates the maximum Efficiency Gap value for scenarios in which the statewide vote-share shifts 1-5% in favor of either party (uniformly among all districts). Smaller values for this metric indicate that both parties waste a similar number of votes, even with small shifts in voter preference. For example, the vote-share scenario in Figure 2b has a better Shifted Efficiency Gap than Figure 2c because the seat outcome does not dramatically change with small vote-share shifts. For a more technical analysis of the Shifted Efficiency Gap and its potential flaws, see DeFord et al. (2020).
- *Partisan Asymmetry:* Partisan Asymmetry observes to what extent both parties receive different seat outcomes for the same vote-share scenarios (Grofman and King 2007). Similar to the Shifted Efficiency Gap, Partisan Asymmetry compares the rate at which both parties win/lose seats as the statewide vote-share shifts uniformly among

(a) Democrats win five seats and Republicans win one seat. Five seats are competitive. The Efficiency Gap is bad because Republicans are cracked. The Shifted Efficiency Gap is bad because small changes in vote-share could dramatically alter the seat outcome. Partisan Asymmetry is good because the district vote-shares are mostly symmetrically distributed.

(b) Democrats and Republicans each win three seats. No seats are competitive. The Efficiency Gap is good because both parties waste votes equally. The Shifted Efficiency Gap is good because increases/decreases in vote-share for either party do not dramatically alter the seat outcome. Partisan Asymmetry is good because the district vote-shares are symmetrically distributed.



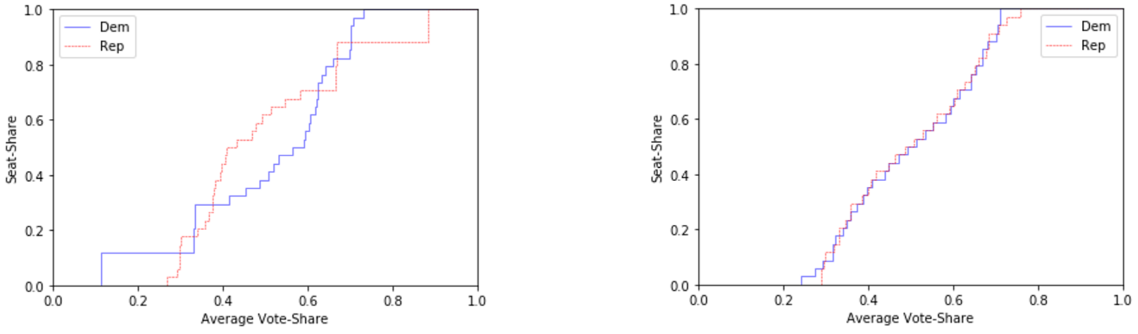
(c) Democrats and Republicans each win three seats. All seats are competitive. The Efficiency Gap is good because both parties waste votes equally. The Shifted Efficiency Gap is bad because small changes in vote-share could dramatically alter the seat outcome. Partisan Asymmetry is good because the district vote-shares are symmetrically distributed.

(d) Democrats and Republicans each win three seats. Two seats are competitive. The Efficiency Gap is good because both parties waste votes equally. The Shifted Efficiency Gap is bad because small changes in vote-share could either change the seat outcome or indicate packing/cracking. Partisan Asymmetry is bad because the district vote-shares are asymmetrically distributed.

Figure 2 **Example vote-share scenarios for six districts. Although the overall vote-share is split 50-50 (assuming equal turnout in all districts), there are a number of different ways the voters can be grouped into districts. Democratic fractions are shown on the bottom in blue and Republican fractions are shown on the top in red.**

all districts. As the vote-share for one party gradually increases to 100% or decreases to 0%, we can observe how many seats that party would hypothetically win for each of those vote-share scenarios. For example, Figure 3 shows the number of seats each party would hypothetically win for vote-shares from 0-100% in two example district plans (these plots are called *vote-seat curves*). The more space exists between the two curves, the more asymmetry is present in the district plan. For the plan in Figure 3a, if Democrats and Republicans were to both win 50% of the votes, they would win 40% and 60% of the seats, respectively. However, for the plan in Figure 3b, Democrats and Republicans each win 50% of the seats for 50% of the votes. In general, there is a large amount of space between the two curves in Figure 3a, while the curves in Figure 3b are nearly identical. Therefore, the plan in Figure 3b is more symmetric than the plan in Figure 3a. The Partisan Asymmetry metric value is calculated as the area between both parties' vote-seat curves (Grofman 1983). This metric typically takes on values between 0.00 and 0.11. The minimum value of zero occurs when the vote-seat curves are exactly the same; however, sometimes factors such as political geography or number of districts can prevent a state from achieving a value of zero. Similarly, the largest value achievable varies slightly from state to state. As a rough guideline, smaller values up to 0.01 indicate very symmetric plans, while larger values such as 0.08-0.11 indicate very asymmetric plans.

As additional examples, the vote-share scenarios in Figures 2b and 2c have small Partisan Asymmetry values because the vote-shares are symmetrically distributed (i.e., both parties are spread evenly across the districts). The vote-share scenario in Figure 2d has a large Partisan Asymmetry value because the vote-shares are asymmetrically distributed.



(a) The vote-seat curves of an asymmetric plan

(b) The vote-seat curves of a symmetric plan

Figure 3 **Vote-seat curves for Democrats and Republicans. The curves in Figure 3a are for an asymmetric district plan and the curves in Figure 3b are for a symmetric district plan.**

- *Competitiveness:* Maintaining competitive districts can encourage voter turnout, reduce district packing, and discourage candidate complacency (Hirano and Snyder

2012, McCarty et al. 2009, Tapp 2018). To assess the competitiveness of a district plan, we display the Democrat/Republican vote-share in each district and report the number of districts within a 10% margin of victory. For example, the vote-shares scenarios in Figures 2a and 2c have many competitive districts, while the scenario in Figure 2b has no competitive districts.

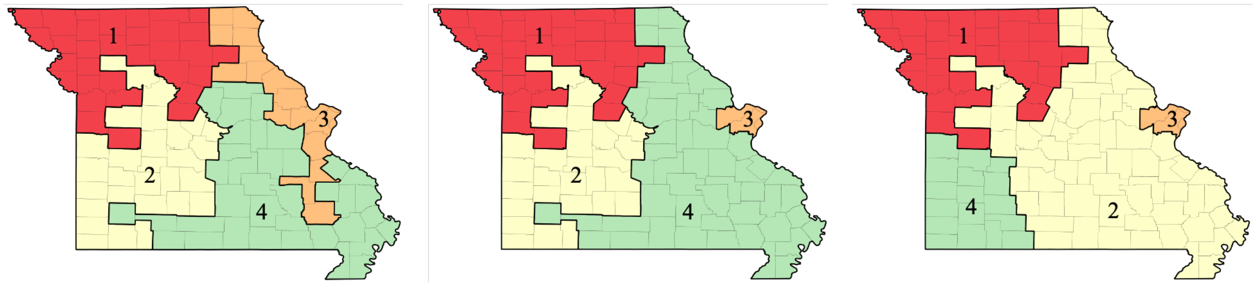
3. Optimization Method

This section describes how the optimization algorithm constructs district plans. In general, the algorithm aims to find a district plan with the best fairness metric value, within the constraints of legal requirements. The algorithm is called a *local search* method, meaning it starts with a given district plan (e.g., the plan currently in place, or another proposed plan) and improves it by making a sequence of small changes to district boundaries. While a single small change might not drastically transform the plan, performing thousands of them can lead to a significant improvement as the algorithm continues to run. The basic steps of the algorithm, based on a method from DeFord et al. (2019), are listed below.

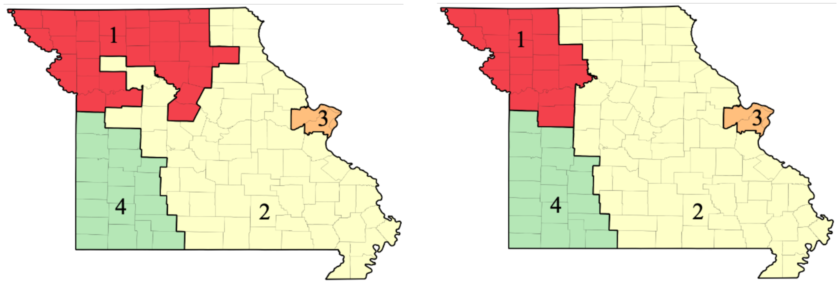
1. Choose an initial district plan, a fairness metric to improve (e.g., compactness, Efficiency Gap), and constraints to enforce (e.g., roughly equal district populations).
2. Randomly choose two neighboring districts.
3. Erase the boundary between these two districts and randomly draw a new boundary that maintains contiguity. Note that this action only affects the two chosen districts.
4. Check whether this new boundary satisfies the constraints chosen in Step 1. If it does not, return to Step 3. If it does, continue to Step 5.
5. Check whether this new boundary improves the chosen fairness metric. If it does not, return to Step 3. If it does, continue to Step 6.
6. Record this boundary. Repeat Steps 3-5 to create a collection of viable new boundaries.
7. From the collection of viable boundaries, select the boundary that yields the greatest improvement in the fairness metric. Update the district plan accordingly. Repeat Steps 2-6 as needed.

Figure 4 shows an example sequence of changes to improve compactness in a four-district plan, using counties as district building blocks. The initial plan (Figure 4a) has convoluted districts with long tendrils. Each algorithm step makes the boundary between two districts less convoluted. After four steps, there are no tendrils and the districts all have simple shapes (Figure 4e).

Section 4 outlines the redistricting constraints used in this algorithm from the Missouri Constitution. Section 5 briefly discusses how the algorithm steps are applied to construct the district plans, and Appendix A provides additional details for algorithm application (including parameter choices and number of iterations).



(a) A plan with convoluted districts (b) The boundary between districts 3 and 4 has been changed. (c) The boundary between districts 2 and 4 has been changed.



(d) The boundary between districts 1 and 4 has been changed. (e) The boundary between districts 1 and 2 has been changed.

Figure 4 **Example steps of the optimization algorithm using a four-district plan at the county level. Each step shows which two districts are changed to improve compactness.**

4. Redistricting in Missouri

This section describes how state legislative and congressional redistricting is conducted in Missouri. We discuss Missouri's geography, the data sources used for our experiments, and the redistricting requirements in the Missouri Constitution.

4.1. Missouri Geography

The discussion of district plans in Section 5 includes references to certain Missouri counties and cities by name, so we provide a brief overview here. Missouri has 114 counties and one independent city (St. Louis City, which we treat as a county in this report); we mainly discuss the most populated counties, since these counties are the most likely to be split between multiple districts. Figure 5 shows where these counties are located within the state. Jackson County and Clay County are in the west; these counties contain most of Kansas City. Greene County is in the south; this county contains the city of Springfield. Boone County is in the center; this county contains the city of Columbia. Franklin County, St. Charles County, Jefferson County, St. Louis County, and St. Louis City are in the east.

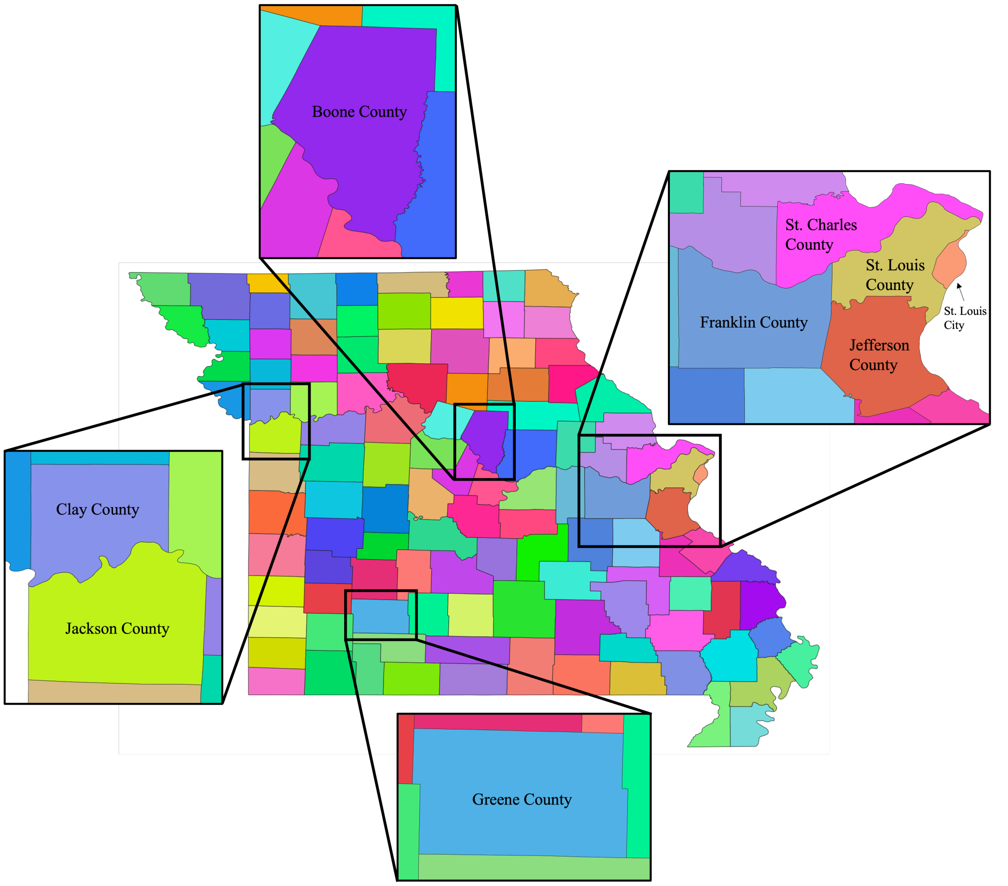


Figure 5 **Missouri counties. Highly populated counties are highlighted using insets. In the west, there is Jackson County and Clay County (the Kansas City area); in the south, there is Greene County (containing the city of Springfield); in the center, there is Boone County (containing the city of Columbia); in the east, there is Franklin County, St. Charles County, Jefferson County, St. Louis County, and St. Louis City (the St. Louis area).**

4.2. Data Sources

Redistricting requires data describing state geography, population, and election results. The data sources used to create district plans for this report are listed below.

- *State geography:* Districts are constructed using geographic units, such as census blocks, census block groups, census tracts, and counties. The U.S. Census Bureau provides spatial data for these units (U.S. Census Bureau 2020b). With spatial data, we can determine which units are neighbors (to enforce district contiguity) and the length of shared borders between neighboring units (to calculate district perimeters for compactness).
- *Population:* In addition to spatial data, the U.S. Census Bureau also provides population counts for geographic units from the 2020 decennial census (U.S. Census Bureau 2020a). Population data are needed to ensure that all districts have roughly equal populations.
- *Demographics:* To comply with the Voting Rights Act of 1965, states typically construct majority-minority districts for congressional district plans (Ballotpedia 2015). To maintain such districts, we use demographic data from the 2020 decennial census (U.S. Census Bureau 2020a).
- *Election results:* While compactness can be calculated with spatial data (i.e., state geography data), the other fairness metrics in Section 2 rely on voting data from past elections. The Missouri Constitution requires the use of voting data averaged from governor, United States Senate, and Presidential races for the past three general elections (2016, 2018, and 2020) (Mo. Const. art. III, §3). These data sets are available at the precinct level on the Harvard Dataverse (Voting and Election Science Team 2021). To construct districts using finer census units (e.g., census block groups), voting data must be disaggregated from the precinct level to the finer level. For this report, we distribute precinct-level voting data proportionally to the block level; from the block level, the voting data are aggregated to block groups or tracts.

With voting data, we can also examine Missouri's political geography. According to this set of data, Missouri voters are roughly 46:5% Democrat and 53:5% Republican. Figure 6 shows which census blocks lean Democrat and which lean Republican. Democratic voters are concentrated in urban centers (such as Kansas City and St. Louis), while Republicans are spread throughout the state. As we discuss in Section 6, this distribution of voters prevents significant improvement to partisan fairness in state legislative plans.

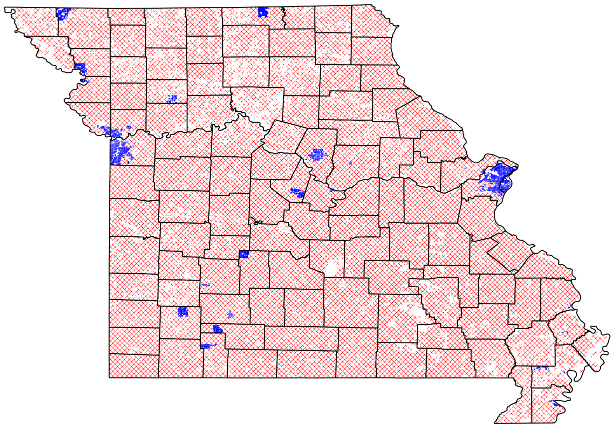


Figure 6 **Voting data for the entire state of Missouri. Democratic blocks are shown in solid blue, Republican blocks are shown in hatched red, and blocks without voters are shown in white. Democratic voters are concentrated in urban centers, while Republicans are more evenly distributed throughout the state.**

4.3. Constitutional Requirements

This section excerpts relevant text from the Missouri Constitution describing the requirements for state legislative and congressional redistricting, and discusses how these requirements are reflected and implemented within our algorithm. The plans in this report satisfy these requirements to the extent possible.

4.3.1. State Legislative Redistricting Requirements Below we discuss the new state legislative redistricting requirements amended to the Missouri Constitution in 2020 (Mo. Const. art. III, §3).

- Population balance:

  Relevant text from the Missouri Constitution: *\Districts shall be as nearly equal as practicable in population, and shall be drawn on the basis of one person, one vote. Districts are as nearly equal as practicable in population if no district deviates by more than one percent from the ideal population of the districts, as measured by dividing the number of districts into the statewide population data being used, except that a district may deviate by up to three percent if necessary to follow political subdivision lines [...]"*

  While the Missouri Constitution did require nearly equal district populations in 2010, it did not specify a maximum allowed percent deviation. The current state legislative district plans do not satisfy this new population requirement, since some districts have a deviation of 3:5-4%. For example, if the current senate plan were redrawn to satisfy this requirement (using the 2010 population data) Jackson County would no longer be able to contain four whole senate districts. All state legislative plans in this report have a maximum 3% deviation from the ideal population. The most notable difference in population distribution between 2010 and 2020 is that Boone County (containing the city of Columbia) now has sufficient population for exactly one senate district.

- No racial discrimination:

  Relevant text from the Missouri Constitution: *\Districts shall be established in a manner so as to comply with all requirements of the United States Constitution and applicable federal laws, including, but not limited to, the Voting Rights Act of 1965 (as amended). The following principles shall take precedence over any other part of this constitution: no district shall be drawn in a manner which results in a denial or abridgement of the right of any citizen of the United States to vote on account of race or color; and no district shall be drawn such that members of any community of citizens protected by the preceding clause have less opportunity than other members of the electorate to participate in the political process and to elect representatives of their choice."*

  The MO-LWV recommended creating as many competitive districts as possible to avoid racial discrimination, so that minority voters are not packed into safe Democratic districts. As noted in Section 5, we were unable to increase the number of competitive seats while maintaining compactness, preserving the same number of whole counties, and satisfying the partisan fairness threshold (explained later in this section). Although we do not incorporate racial data into the algorithm for state legislative plans, Section 6 lists the number of majority-minority districts for each state senate/house plan (defined as a district in which the non-Hispanic white population accounts for less than 50% of the total district population).

- Contiguity and compactness:

  Relevant text from the Missouri Constitution: *\Subject to the requirements of [population balance and no racial discrimination], districts shall be composed of contiguous territory as compact as may be. Areas which meet only at the points of adjoining corners are not contiguous. In general, compact districts are those which are square, rectangular, or hexagonal in shape to the extent permitted by natural or political boundaries."*

All state legislative plans in this report are contiguous and optimized for compactness.

- Preservation of political subdivisions:

  Relevant text from the Missouri Constitution: \ *To the extent consistent with [population balance, no racial discrimination, contiguity, and compactness], communities shall be preserved. Districts shall satisfy this requirement if district lines follow political subdivision lines to the extent possible, using the following criteria, in order of priority. First, each county shall wholly contain as many districts as its population allows. Second, if a county wholly contains one or more districts, the remaining population shall be wholly joined in a single district made up of population from outside the county. If a county does not wholly contain a district, then no more than two segments of a county shall be combined with an adjoining county. Third, split counties and county segments, defined as any part of the county that is in a district not wholly within that county, shall each be as few as possible. Fourth, as few municipal lines shall be crossed as possible."*

  Although this requirement mentions municipal lines, and the MO-LWV expressed a desire to follow school district boundaries as well, we focus on maintaining county lines; too many very specific constraints can cause an automated algorithm to struggle to find good district plans. Therefore, the plans presented in Section 5 might not follow municipal lines or school district boundaries. For a similar reason, the algorithm does not explicitly enforce the second requirement (which refers to the remaining population of a county that wholly contains one or more districts). Therefore, the state legislative plans in this report may require manual adjustment to more effectively preserve political subdivisions.

  The algorithm uses a few different methods to preserve county lines. First, the plans in this report are constructed using a combination of counties, census tracts, census block groups, and census blocks. Although district plans are typically drawn using census blocks, the smallest geographic unit for which the census collects information, population balance is still achievable with these larger units. Automatically keeping counties with low population intact helps preserve county lines, and using other larger units also helps maintain compact districts.