

# Illinois Congressional Redistricting for 2021

Kiera W. Dobbs, Rahul Swamy, Douglas M. King

Department of Industrial and Enterprise Systems Engineering, University of Illinois Urbana-Champaign, Urbana, IL 61801  
kdobbs2@illinois.edu, rahulswa@illinois.edu, dmking@illinois.edu

Ian G. Ludden, Sheldon H. Jacobson

Department of Computer Science, University of Illinois Urbana-Champaign, Urbana, IL, 61801  
iludden2@illinois.edu, shj@illinois.edu

9 August 2021

---

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

<b>1</b>	<b>Executive Summary</b>	<b>3</b>
<b>2</b>	<b>Introduction</b>	<b>5</b>
<b>3</b>	<b>Fairness Metrics</b>	<b>5</b>
<b>4</b>	<b>Optimization Method</b>	<b>9</b>
<b>5</b>	<b>Redistricting in Illinois</b>	<b>10</b>
5.1	Data Sources . . . . .	10
5.2	Constitutional Requirements . . . . .	11
<b>6</b>	<b>District Plans</b>	<b>13</b>
6.1	Compact Plans . . . . .	13
6.2	Efficiency Gap Plans . . . . .	14
6.3	Competitive Plans . . . . .	14
6.4	Partisan Asymmetry Plans . . . . .	14
<b>7</b>	<b>Discussion</b>	<b>28</b>
7.1	Limitations . . . . .	31
<b>A</b>	<b>Additional Technical Details</b>	<b>32</b>
<b>B</b>	<b>Compact Plans - Three Majority-Minority Districts</b>	<b>35</b>

## 1. 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. Since Illinois lost a congressional seat following the 2020 census, a new congressional district plan cannot simply maintain the cores of the current districts; all districts must have a larger population, to compensate for the lost seat. Completely redrawing district boundaries provides an opportunity to improve fairness and transparency in the districting process. The goal of this analysis is to examine the physical and partisan characteristics of Illinois congressional district plans with 17 districts (instead of 18) that satisfy constitutional requirements.

We use an optimization algorithm to create a diverse collection of congressional district plans for Illinois that satisfy constitutional requirements and prioritize different fairness objectives (e.g., compactness, the Efficiency Gap). It is 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) are due to gerrymandering or are a natural result of constitutional requirements and political geography. Optimization algorithms promote transparency in each step of the redistricting process, since they have clearly defined objectives, constraints, and parameters. Although Illinois does not have additional congressional redistricting requirements (beyond those required by the U.S. Constitution), focusing on multiple aspects of fairness can illustrate how constitutional requirements and political geography affect the level of political fairness achievable for Illinois. 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 there are multiple options for the Illinois congressional district plan that achieve a good level of political fairness while a) maintaining four majority-minority districts and b) maintaining reasonably compact districts.** This conclusion is based on the following observations:

- District plans created to solely prioritize compactness tend to pack Democratic voters, since Democrats are heavily concentrated in the Chicago area.

- Many Democratic votes are considered wasted in plans that solely prioritize compactness, since packed Democratic districts tend to have many more votes than are needed to win their elections (this is the case despite Democrats winning the majority of votes and seats in Illinois).
- In contrast, district plans created to prioritize the Efficiency Gap, competitiveness, or Partisan Asymmetry *and* maintain compactness have better levels of political fairness, and tend to have district shapes comparable to plans that *solely* prioritize compactness.

---

## 2. Introduction

Illinois lost a congressional seat following the 2020 census. Therefore, a new congressional district plan cannot simply maintain the cores of the current districts; all districts must have a larger population, to compensate for the lost seat. Completely redrawing district boundaries provides an opportunity to improve fairness and transparency in the districting process.

This report presents a diverse collection of congressional district plans for Illinois. The plans are constructed with an optimization algorithm to promote transparency in the districting process. Some plans presented in this report prioritize compactness, while others prioritize partisan aspects of fairness (e.g., the Efficiency Gap). Although the Illinois Constitution does not list additional state requirements for congressional redistricting, focusing on multiple aspects of fairness allows one to examine how requirements from the U.S. Constitution (e.g., majority-minority districts) and political geography affect the level of political fairness achievable for Illinois. Each plan is scored with various fairness metrics, and the advantages and disadvantages between plans are discussed. **The results show that district plans that solely prioritize compactness have an inherent Republican advantage; however, it is possible to substantially improve partisan fairness while maintaining reasonably compact districts.**

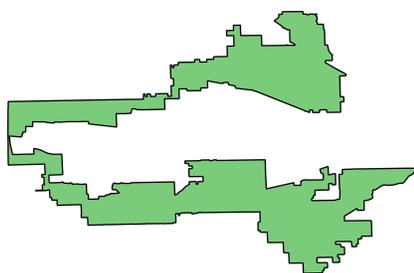
This report is organized as follows. Section 3 describes the fairness metrics used to evaluate district plans. Section 4 gives an overview of the optimization method used to construct the plans that optimize these fairness metrics. Section 5 outlines redistricting requirements in the U.S. Constitution and relevant data. Lastly, Section 6 presents the district plans and Section 7 discusses and compares their partisan characteristics.

## 3. Fairness Metrics

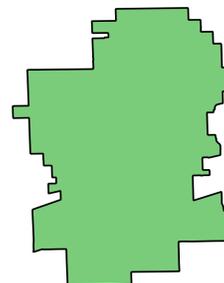
In the context of redistricting, “fairness” can be interpreted in a number of ways. Sometimes fairness focuses on political parties; for example, a district plan could be considered fair if neither party is *packed* and *cracked* (i.e., concentrated in a few districts where it wins by overwhelming margins, 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* in 1812 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 Illinois’s state boundary, since the state boundary will always overlap with district perimeter segments for any district plan. A district with an irregular shape (such as Illinois’s fourth congressional district 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) Illinois’s fourth congressional district in the Chicago area (U.S. Census Bureau 2020) with a perimeter of approximately 220 miles

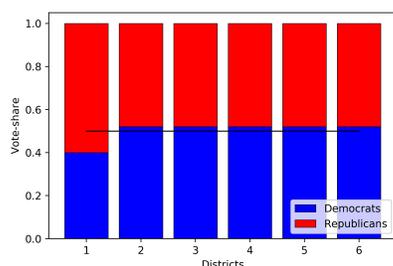


(b) A compact district with a perimeter of approximately 87 miles

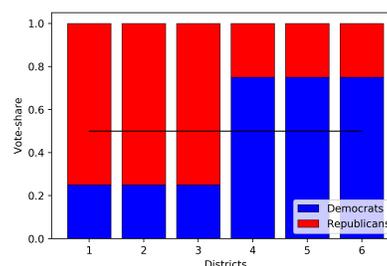
**Figure 1** Two examples of district shapes (for roughly the same location in the Chicago area). Figure 1a shows a non-compact district and Figure 1b shows a compact district.

- 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

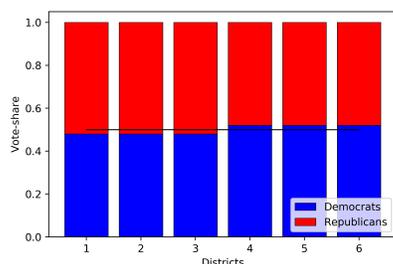
the total votes cast for these two parties (Stephanopoulos and McGhee 2015). Smaller values of this metric indicate that both parties waste a similar number of votes, which means both parties are packed and cracked to a similar degree. For example, the vote-share scenario in Figure 2a has a large Efficiency 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.



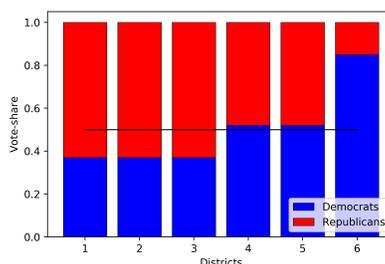
(a) Democrats win five seats and Republicans win one seat. Five seats are competitive. The Efficiency Gap is bad because Republicans are cracked. Partisan Asymmetry is good because the district vote-shares are mostly symmetrically distributed.



(b) Democrats and Republicans each win three seats. No seats are competitive. The Efficiency Gap is good because both parties waste votes equally. 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. 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. Partisan Asymmetry is bad because the district vote-shares are asymmetrically distributed.

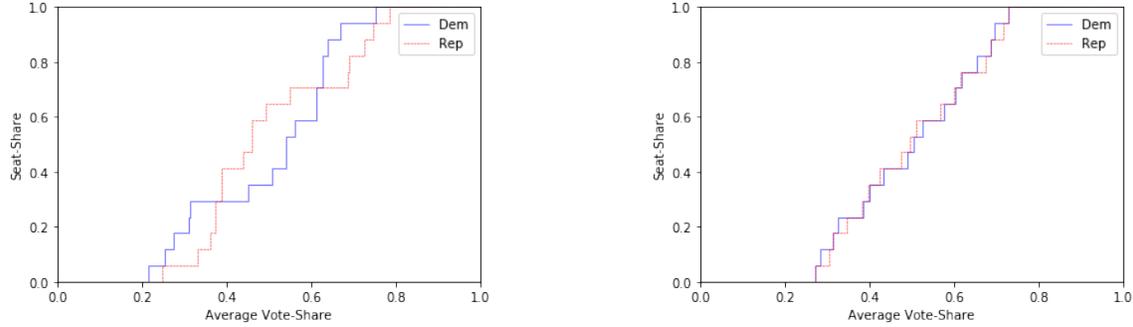
**Figure 2** Example vote-share scenarios for six districts. Although the overall vote-share is split 50-50 (assuming equal turnout in all districts), there are a number of ways the voters can be grouped into districts.

- *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.

- Partisan Asymmetry: Partisan Asymmetry observes to what extent both parties receive different seat outcomes for the same vote-share scenarios (Grofman and King 2007). Partisan Asymmetry compares the rate at which both parties win/lose seats as the statewide vote-share shifts uniformly among 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 that 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 roughly 35% and 65% of the seats, respectively. However, for the plan in Figure 3b, Democrats and Republicans each win roughly 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.

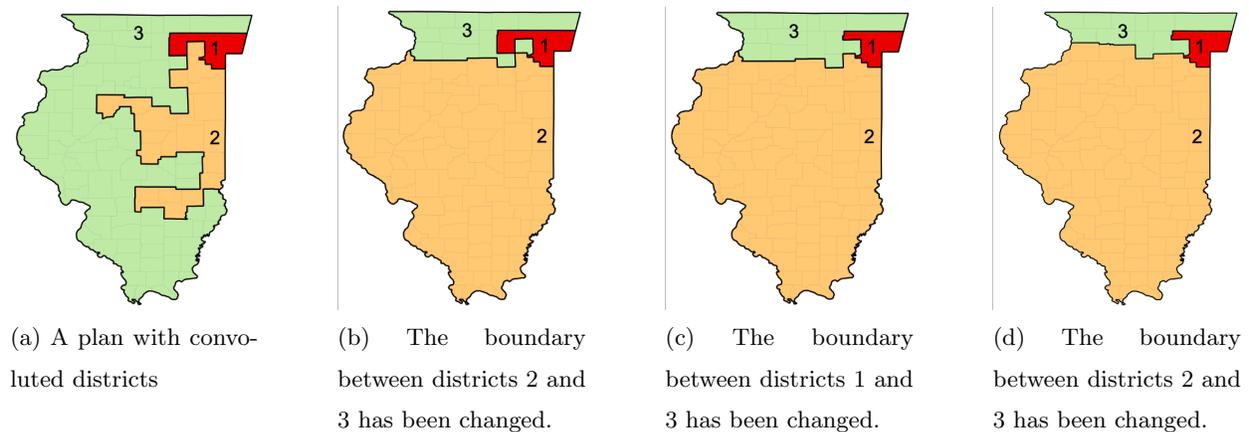
## 4. Optimization Method

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 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. Appendix A provides additional details for algorithm application (including parameter choices and number of iterations).

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 three-district plan, using counties as district building blocks. The initial plan (Figure 4a) has convoluted districts with tendrils. Each algorithm iteration makes the boundary between two districts less convoluted. After three iterations, there are no tendrils and the districts have simpler shapes (Figure 4d).



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

## 5. Redistricting in Illinois

This section describes how congressional redistricting is conducted in Illinois. We discuss the political geography of Illinois, the data sources used for our experiments, and the redistricting requirements in the U.S. Constitution.

### 5.1. Data Sources

Congressional redistricting in Illinois requires data describing state geography, population, demographics, 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 2010 U.S. Census provides spatial data for these units (U.S. Census Bureau 2010). With spatial data, we

---

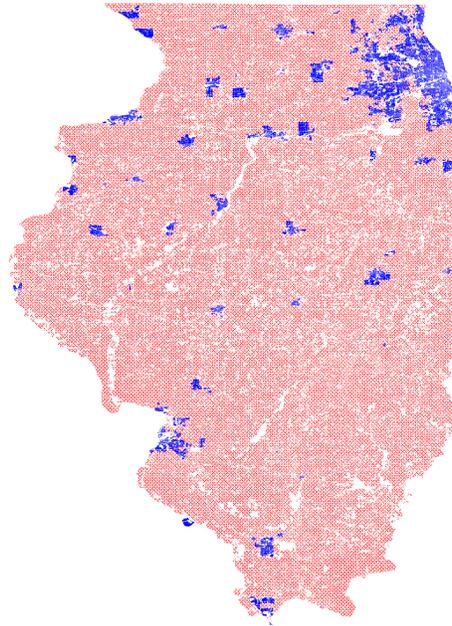
can determine which units are neighbors (to enforce district contiguity) and the length of shared borders between neighboring units (to calculate district perimeters for compactness).

- *Population:* In addition to spatial data, the U.S. Census also provides population counts for geographic units (U.S. Census Bureau 2010). Population data are needed to ensure that all districts have roughly equal populations. Since the 2020 population data are not yet available, the plans in this report use the 2019 American Community Survey five-year population estimates (American Community Survey 2019). The plans will be updated once the 2020 population data are available.
- *Demographics:* To comply with the Voting Rights Act of 1965, states typically construct majority-minority districts (Ballotpedia 2015). To maintain such districts, we use demographic data from the 2019 American Community Survey five-year estimates (American Community Survey 2019).
- *Election results:* While compactness can be calculated with spatial data (i.e., state geography data), the other fairness metrics in Section 3 rely on voting data from past elections. To construct districts using finer census units (e.g., census tracts), voting data must be disaggregated from the county or precinct level to the finer level. In this report, we construct and analyze plans using the available precinct-level voting data (distributed proportionally to census blocks) from the United States Senate and Presidential races in the 2016 election (OpenPrecincts 2020).

We can also use the voting data to examine Illinois’s political geography. According to this set of data, Illinois is roughly 58.3% Democrat and 41.7% Republican. Figure 5 shows how voters are distributed throughout the state. Democratic voters are concentrated in urban centers (such as Chicago), while Republicans are more evenly distributed in the rest of the state. As discussed in Section 6, this distribution of voters causes compact district plans to pack Democratic voters into urban districts.

## 5.2. Constitutional Requirements

The U.S. Constitution requires congressional districts to be equi-populous and comply with the Voting Rights Act of 1965 (NCSL 2019); the Illinois Constitution does not impose additional requirements for congressional redistricting. Below we list how the plans in this report satisfy these requirements.



**Figure 5** Voting data for the entire state of Illinois. 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 (such as Chicago), while Republicans are more evenly distributed throughout the state.

- Population balance: Typically, congressional district populations deviate from the ideal district population (i.e., the total state population divided by the number of districts) by at most one person (NCSL 2019). Single-person population balance is achievable when districts are constructed with census blocks, the smallest geographic census unit. For computational efficiency, the plans in this report are constructed with census tracts (a larger census unit); hence, we allow districts to deviate by at most 0.5% from the ideal population. The plans presented can then be manually tuned to single-person population balance using census blocks without significantly altering district structure.
- Voting Rights Act: The current Illinois congressional plan has four majority-minority districts: two districts with Black/African-American majorities, one district with a Latino/Hispanic majority, and one district with a white minority and no majority (Ballotpedia 2015). Even though Illinois lost a congressional seat following the 2020 census, we maintain four majority-minority districts with the same composition.

Although not explicitly required, all plans in this report are contiguous and most are reasonably compact; some plans are explicitly optimized for compactness, while others are optimized for different fairness metrics. In the latter cases, compactness is maintained as much as possible.

## 6. District Plans

Here we present a collection of congressional district plans for Illinois, following the constitutional requirements discussed in Section 5.2 and optimized for the different fairness metrics discussed in Section 3.

Illinois lost a congressional seat following the 2020 census; now there are 17 congressional districts and the ideal district population is 751,214. Illinois has 3,123 census tracts, which we use to construct the plans. The district plans in this section can be categorized in the following manner. For each type of plan, we provide three different options.

- Compact plans: These plans were optimized solely for compactness. No effort was made to improve other fairness metrics.
- Efficiency Gap plans: First, these plans were optimized for the Efficiency Gap (i.e., the algorithm tries to make this value as small as possible). Once the plans have a small Efficiency Gap value, the algorithm maintains this small value while improving compactness.
- Partisan Asymmetry plans: Similar to the approach taken to produce the Efficiency Gap plans, the algorithm first decreases the Partisan Asymmetry value as much as possible, and then improves compactness while maintaining a small value.
- Competitive plans: For these plans, the algorithm simultaneously improves compactness and competitiveness; every competitive district encountered while improving compactness is maintained.

Note that some sets of district plans were constructed with multiple algorithm phases (i.e., first a plan is optimized for a partisan fairness metric, then the plan is optimized for compactness). Appendix A gives additional details for plan construction, including a discussion of these phases.

### 6.1. Compact Plans

Figures 6, 7, and 8 display the compact congressional plans (COMP1, COMP2, and COMP3, respectively). The districts in these plans are fairly circular/rectangular outside

of the Chicago area; districts in the Chicago area tend to have more irregular shapes. For example, Figure 6a shows very compact districts outside of the Chicago area, while some districts shown in Figure 6b are slightly elongated and one district is somewhat snake-like. In Figure 8b, some districts have mild tendrils. These irregular shapes may be the result of maintaining the four majority-minority districts. For comparison, Appendix B shows compact congressional plans with only three majority-minority districts; the Chicago area has more compact districts in those plans than in COMP1, COMP2, and COMP3.

### **6.2. Efficiency Gap Plans**

Figures 9, 10, and 11 display the Efficiency Gap congressional plans (EG1, EG2, and EG3, respectively). The district shapes are reasonable, though slightly more irregular than the compact plans. For example, Figure 9a shows an L-shaped district in the north, Figure 10a shows an elongated district in the northwest, and one of the majority-minority districts in Figure 11b consists of two areas joined by a thin connector. These differences in district shapes may be a result of the algorithm trying to more evenly distribute voters among the districts.

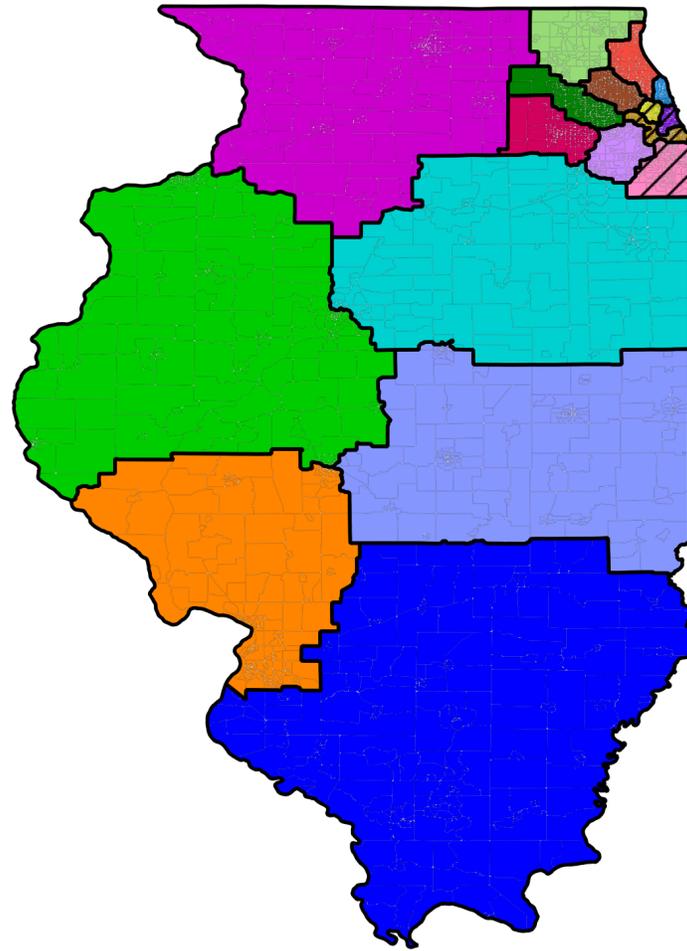
### **6.3. Competitive Plans**

Figures 12, 13, and 14 display the competitive congressional plans (CMPTTV1, CMPTTV2, and CMPTTV3, respectively). As with the Efficiency Gap plans, the district shapes are largely comparable to the compact plans. CMPTTV1 is the most compact (among the competitive plans); the only odd-shaped district is one of the majority-minority districts in Figure 12b. CMPTTV2 also has generally compact districts, although one district in the northeast wraps around the Chicago area (Figure 13a). CMPTTV3 has more irregular district shapes outside of the Chicago area (Figure 14a), and two of the majority-minority districts in Figure 14b are slightly elongated.

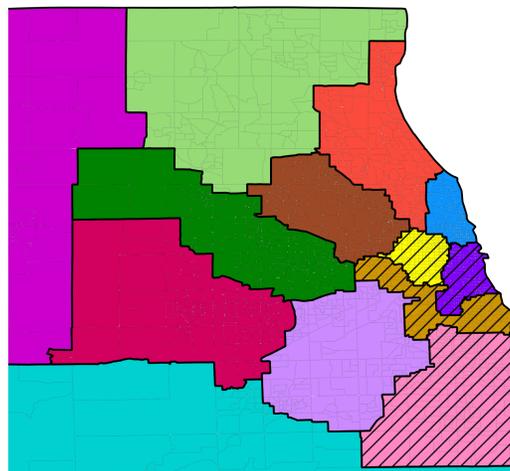
### **6.4. Partisan Asymmetry Plans**

Figures 15, 16, and 17 display the Partisan Asymmetry congressional plans (PA1, PA2, and PA3, respectively). The districts in these plans are considerably less compact than the districts in COMP1/2/3. Many Chicago districts in PA1 and PA3 (Figures 15b and 17b) are elongated; this may result from districts trying to reach a politically diverse collection of voters (i.e., Democrats in Chicago and Republicans outside of Chicago). Two of the majority-minority districts in PA1 are especially snake-like; this may result from

the districts maintaining a majority-minority population in addition to redistributing their typically high concentration of Democratic voters. PA2 has an odd-shaped district as well; Figure 16a shows a northern district with an arm reaching into the Chicago area. However, the overall district shapes for PA2 are more similar to COMP1/2/3 than to PA1/3.

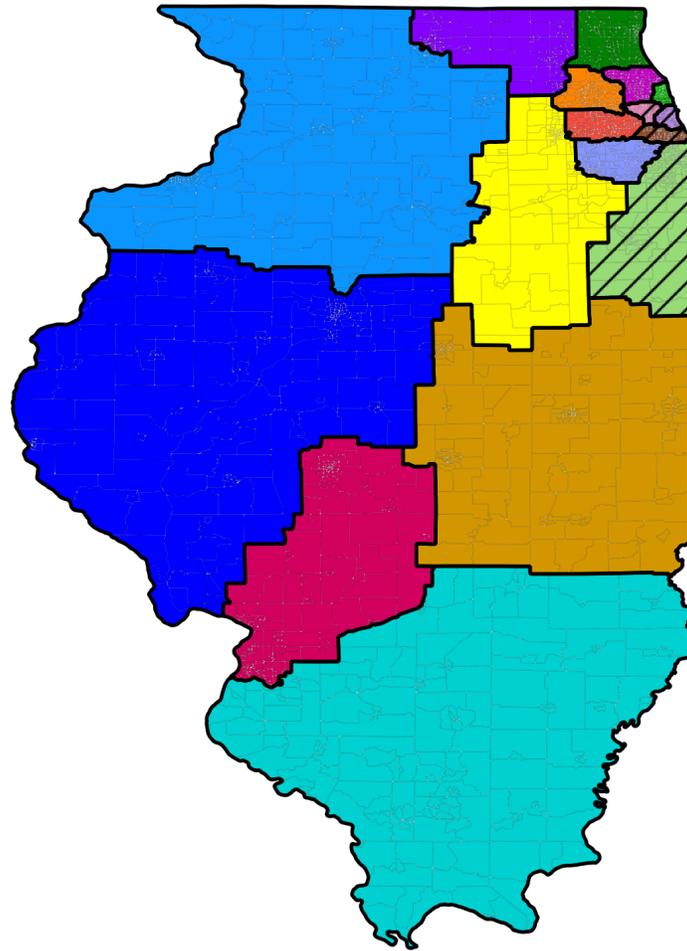


(a) COMP1

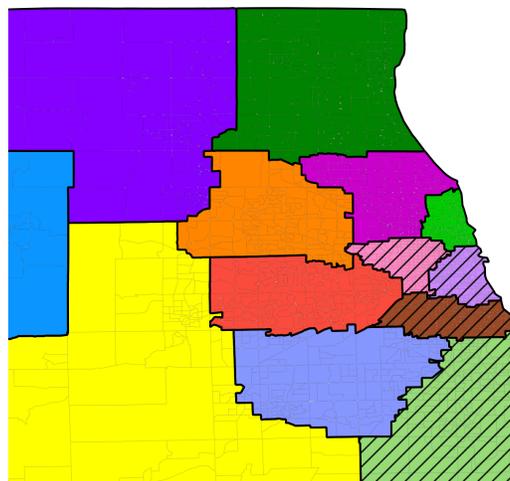


(b) The Chicago area

**Figure 6** A congressional plan optimized for compactness (COMP1), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

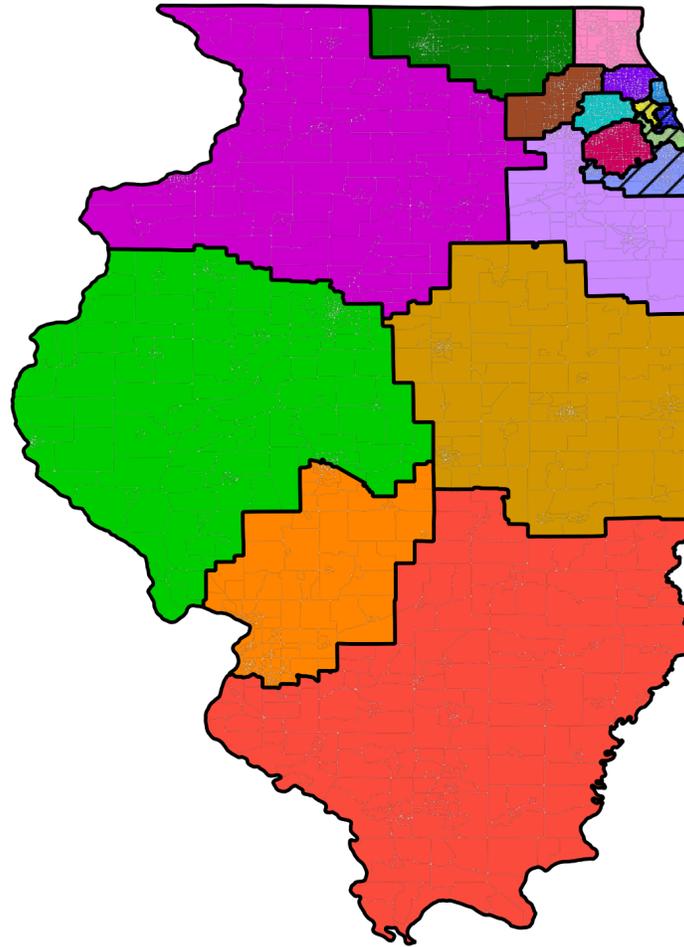


(a) COMP2

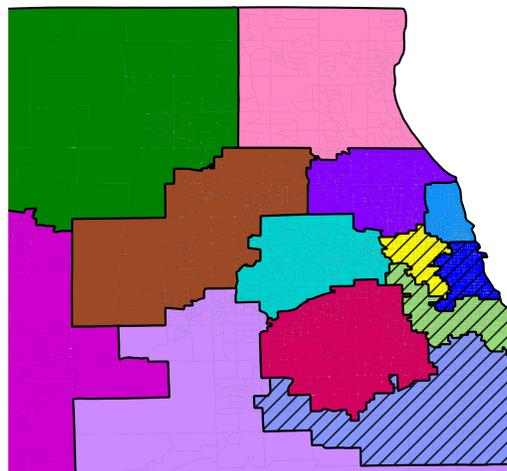


(b) The Chicago area

**Figure 7** A congressional plan optimized for compactness (COMP2), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

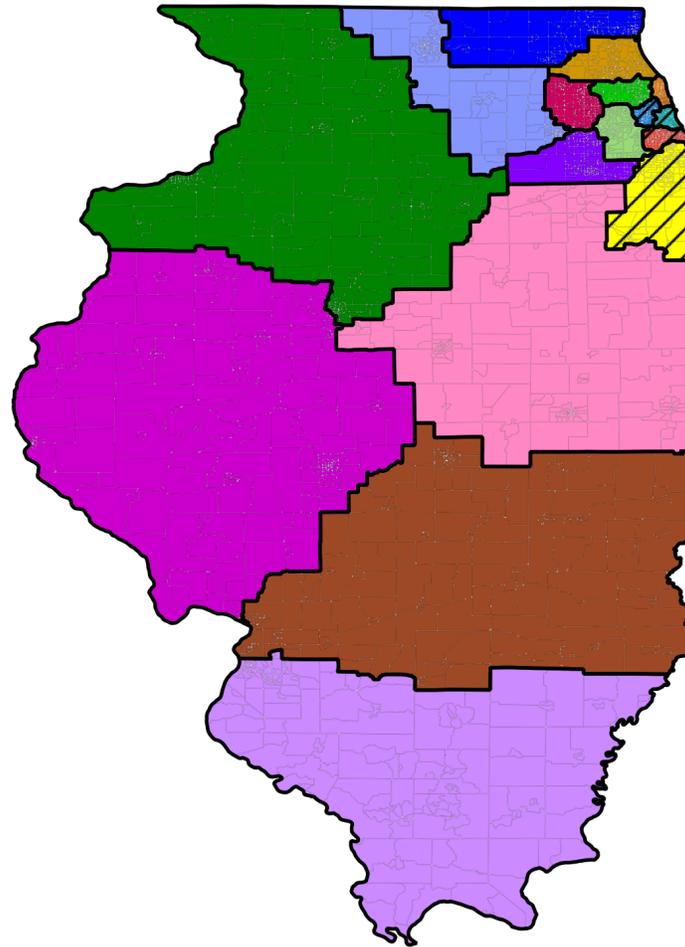


(a) COMP3

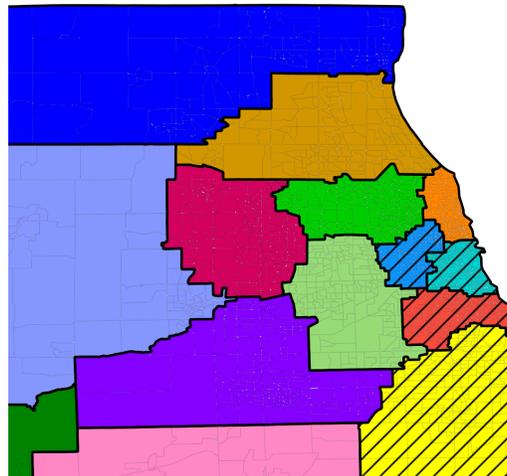


(b) The Chicago area

**Figure 8** A congressional plan optimized for compactness (COMP3), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

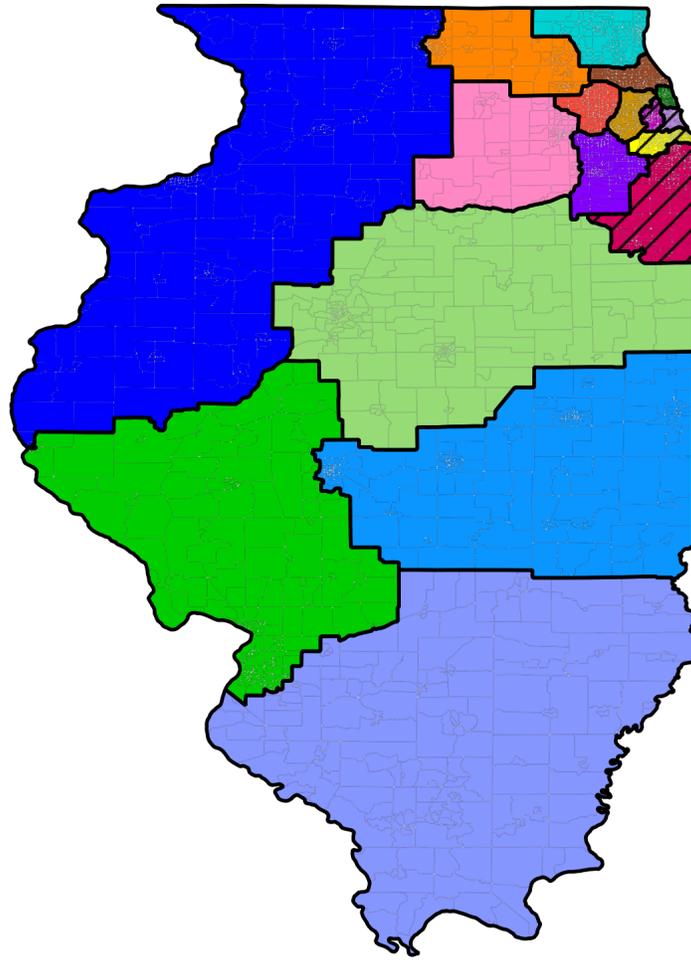


(a) EG1

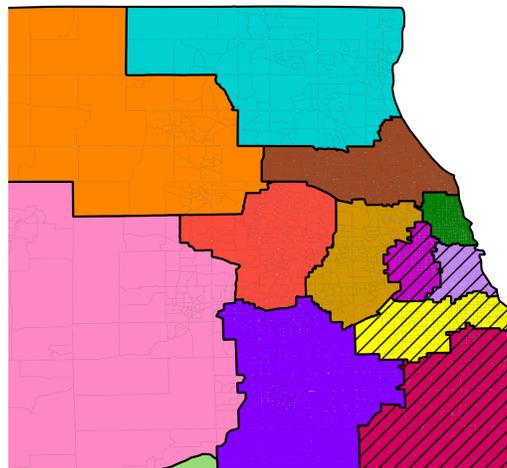


(b) The Chicago area

**Figure 9** A congressional plan optimized for the Efficiency Gap (EG1), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

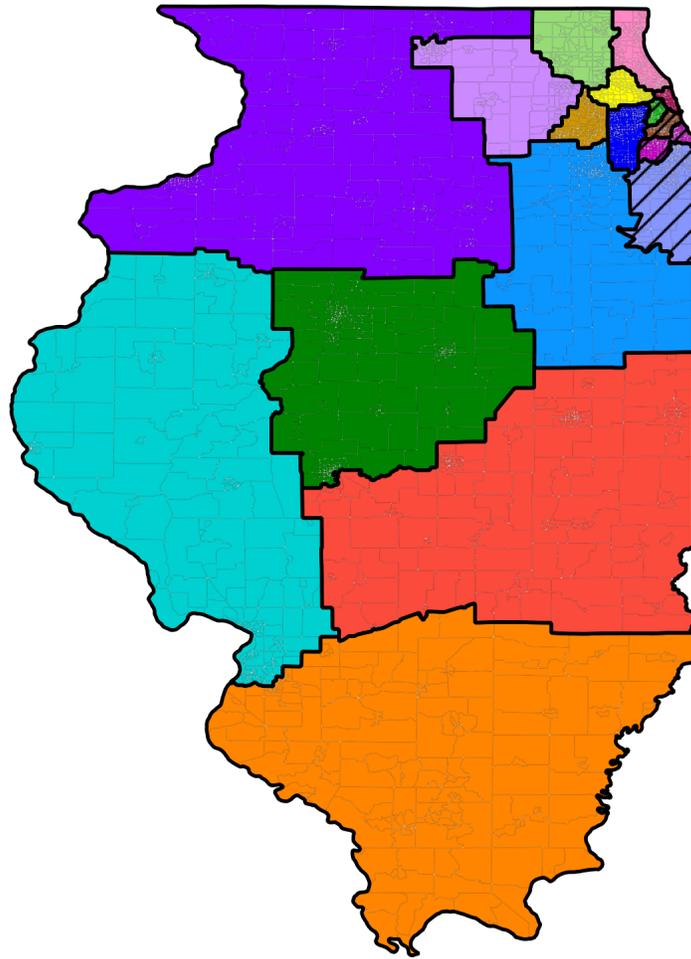


(a) EG2

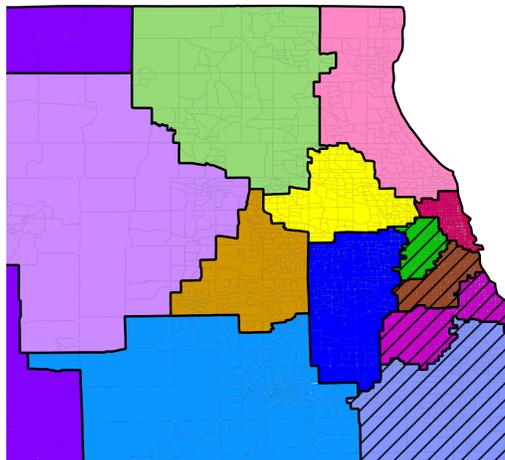


(b) The Chicago area

**Figure 10** A congressional plan optimized for the Efficiency Gap (EG2), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

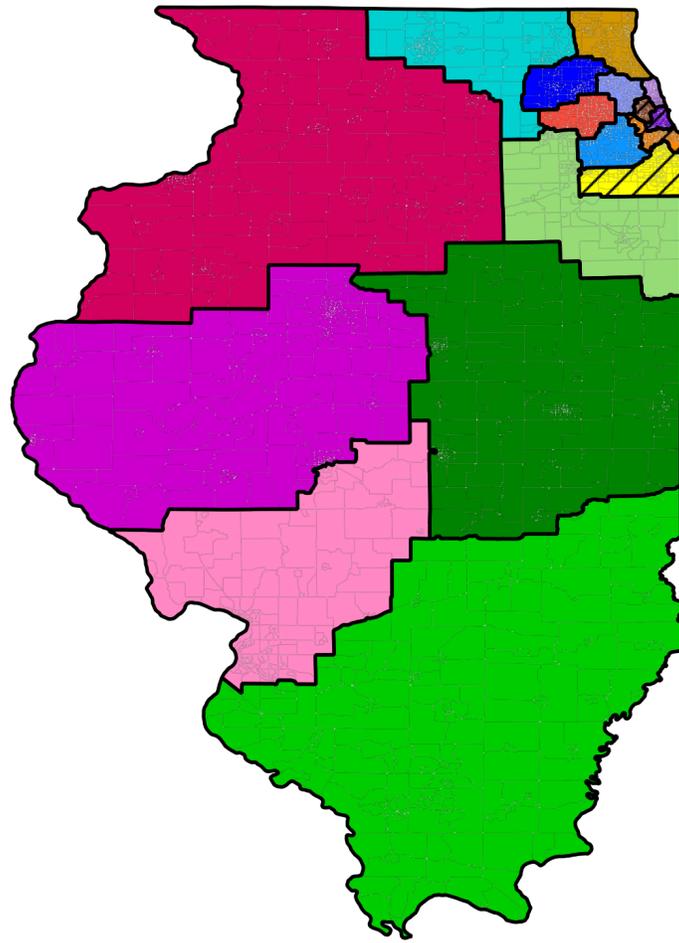


(a) EG3

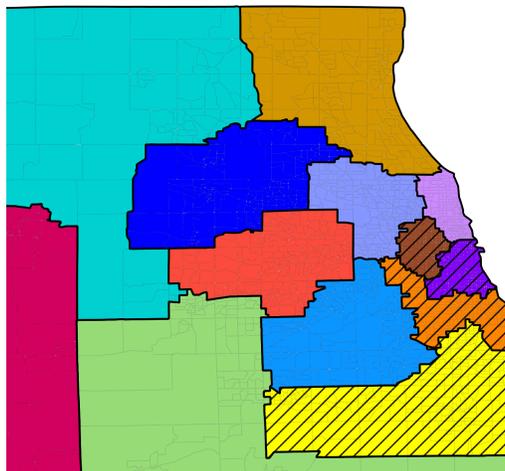


(b) The Chicago area

**Figure 11** A congressional plan optimized for the Efficiency Gap (EG3), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

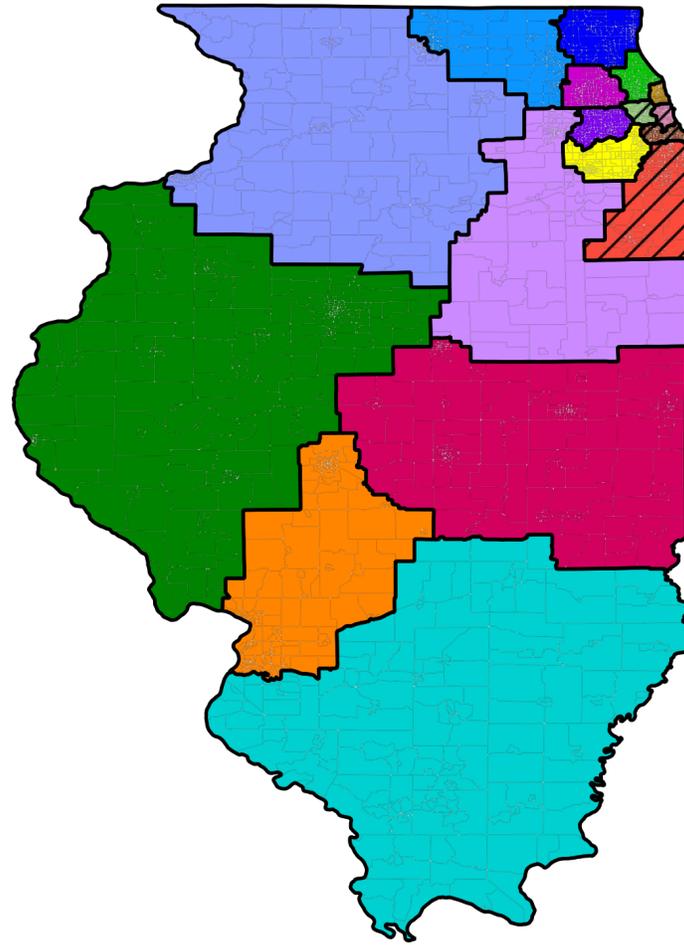


(a) CMPTTV1

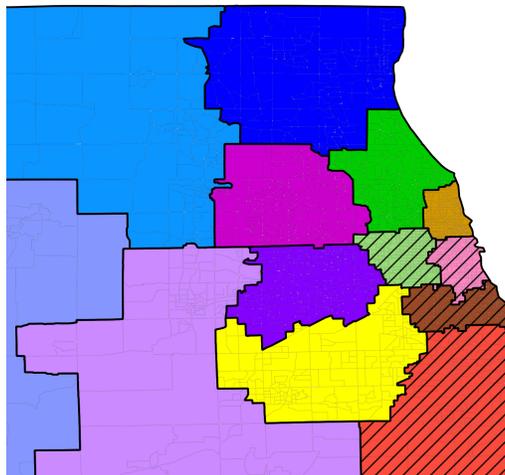


(b) The Chicago area

**Figure 12** A congressional plan optimized for competitiveness (CMPTTV1), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

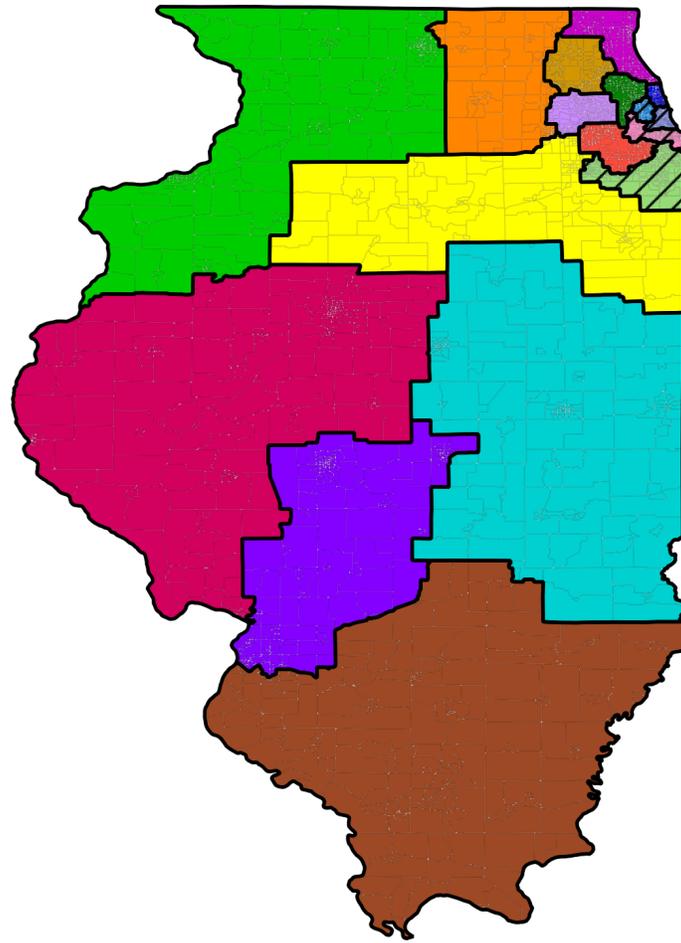


(a) CMPTTV2

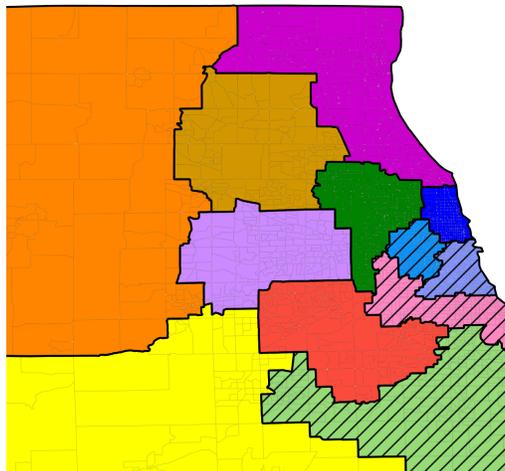


(b) The Chicago area

**Figure 13** A congressional plan optimized for competitiveness (CMPTTV2), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

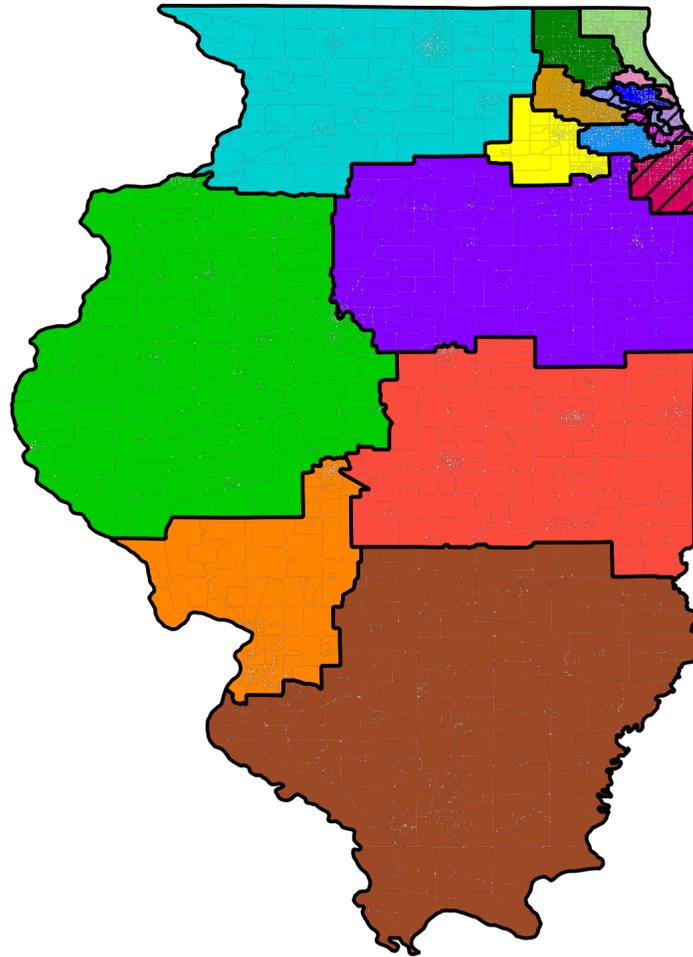


(a) CMPTTV3

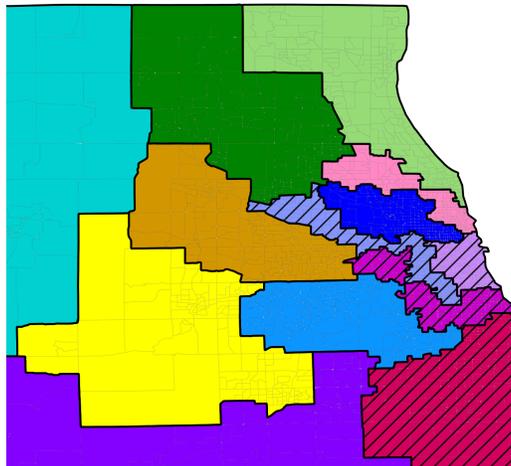


(b) The Chicago area

**Figure 14** A congressional plan optimized for competitiveness (CMPTTV3), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

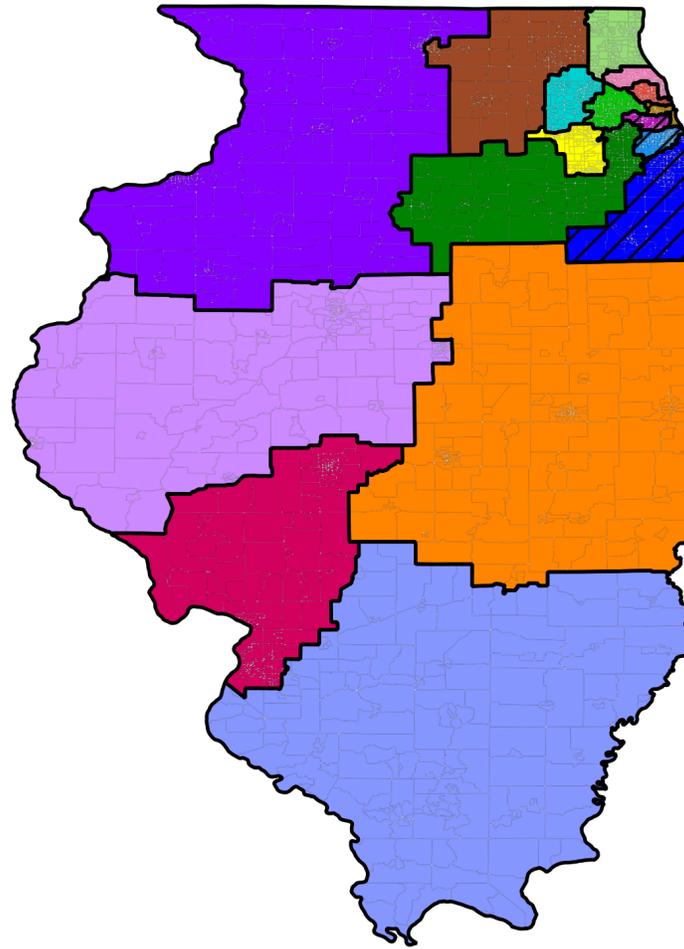


(a) PA1

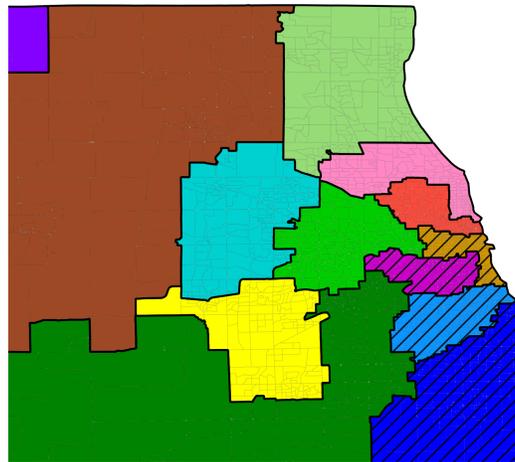


(b) The Chicago area

**Figure 15** A congressional plan optimized for Partisan Asymmetry (PA1), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

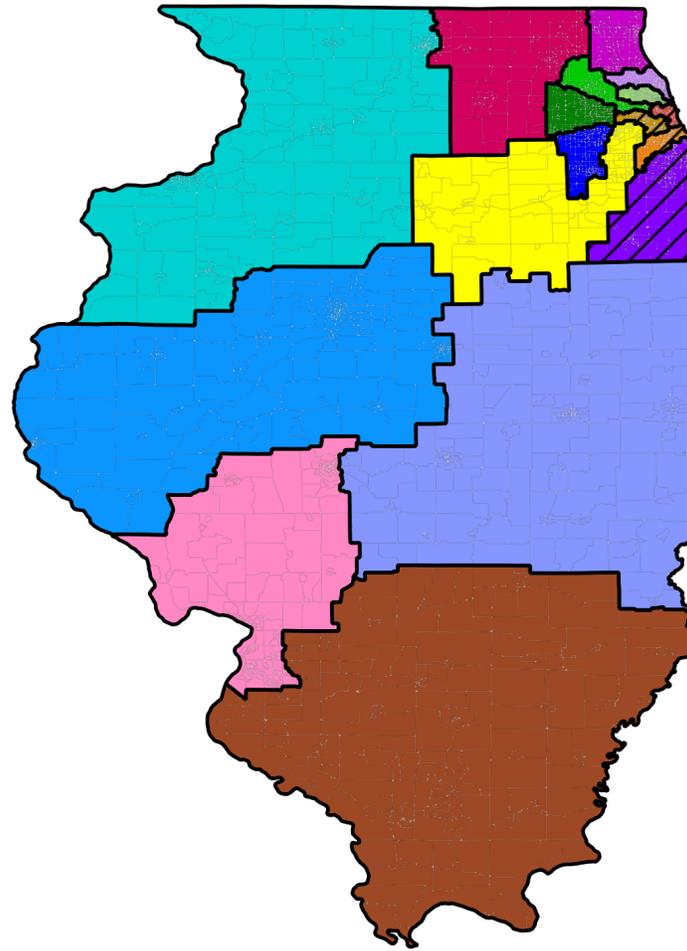


(a) PA2

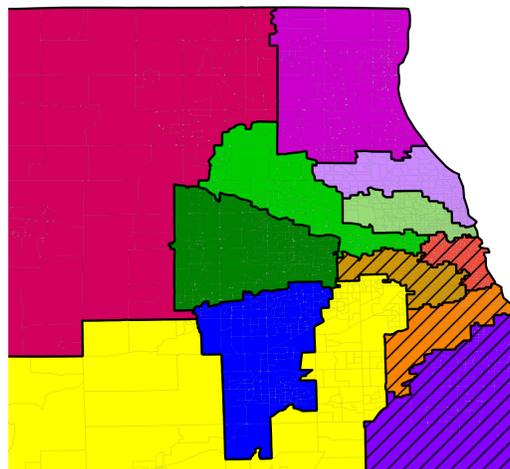


(b) The Chicago area

**Figure 16** A congressional plan optimized for Partisan Asymmetry (PA2), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.



(a) PA3



(b) The Chicago area

**Figure 17** A congressional plan optimized for Partisan Asymmetry (PA3), with a closer view of the Chicago area. District boundaries are shown in black and majority-minority districts have black stripes.

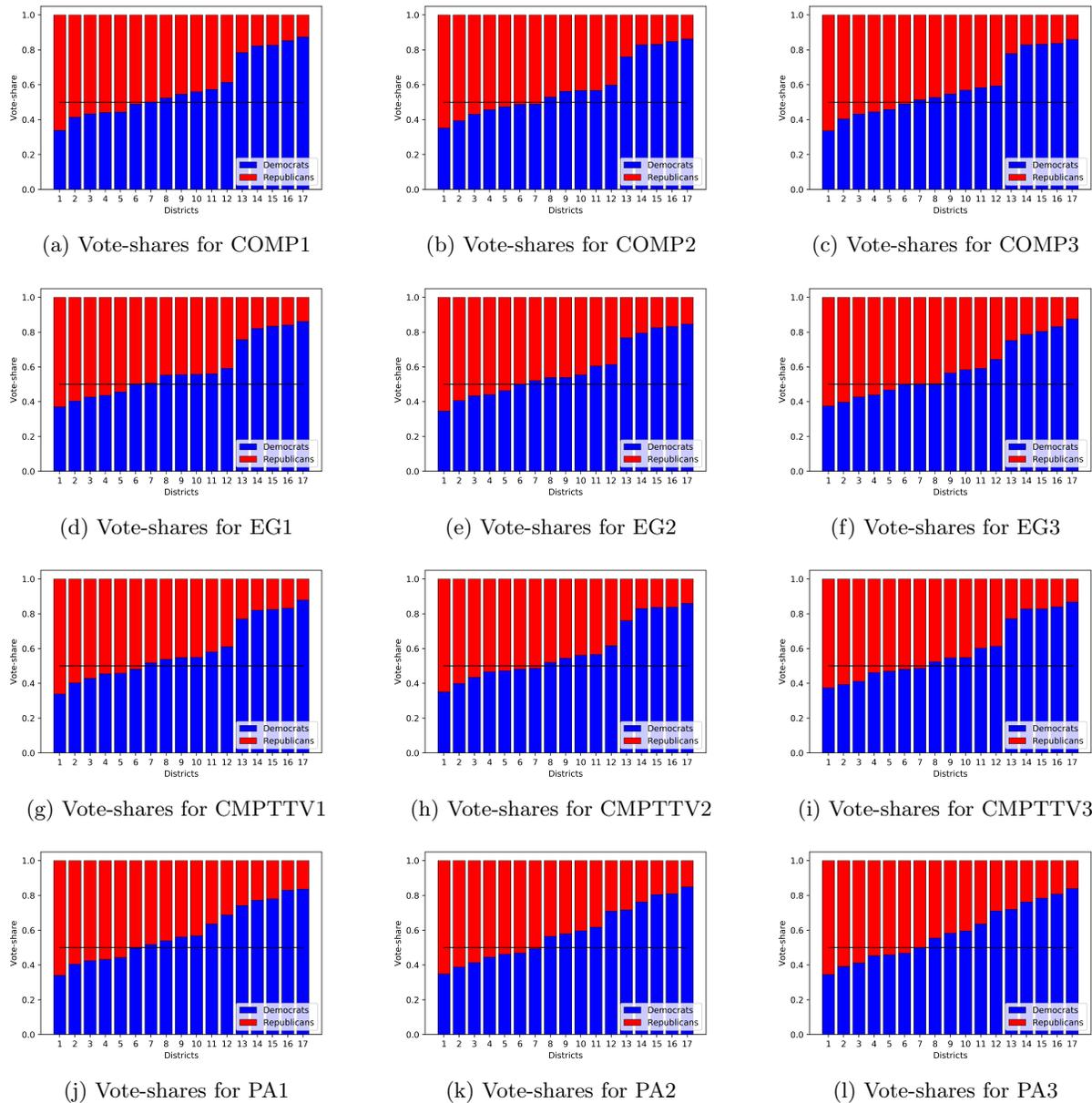
## 7. Discussion

This section reports the metric values for each plan, examines the trade-offs between plans, and discusses the fairness metric values that are achievable for Illinois given its voter distribution and redistricting requirements.

Plan	Comp	EG	PA	Cmpttv
COMP1	5,387	9.51%	0.077	4
COMP2	5,500	8.86%	0.079	5
COMP3	5,642	3.46%	0.073	5
EG1	5,649	1.87%	0.072	3
EG2	5,687	1.96%	0.061	5
EG3	5,880	1.97%	0.058	4
CMPTTV1	5,570	3.52%	0.072	7
CMPTTV2	5,690	8.77%	0.083	6
CMPTTV3	6,025	9.01%	0.079	7
PA1	5,756	3.55%	0.029	3
PA2	5,950	10.0%	0.024	3
PA3	6,129	9.87%	0.019	4

**Table 1** The metric values for the congressional district plans. From left to right, the table lists each plan’s compactness (Comp), Efficiency Gap (EG), Partisan Asymmetry (PA), and the number of seats within a 10% margin of victory (Cmpttv).

The COMP1/2/3 plans in Section 6.1 prioritize compactness, hence they are the most visually appealing district plans in this report. However, it is also important to examine how solely prioritizing compactness affects the partisan characteristics of these district plans. Table 1 shows that the district plans optimized for compactness have pro-Republican biases, even when districting goals are not explicitly political; most Democratic voters are heavily concentrated in the Chicago area, so optimizing for compactness packs urban districts with Democrats. For example, COMP3 has a reasonable Efficiency Gap of 3.46%, while COMP1 and COMP2 have inferior values of 8.86% and 9.51%, respectively. Figures 18a, 18b, 18c show that Democrats may narrowly win a competitive district in COMP3 that they narrowly lose in COMP1 and COMP2; this improves the Efficiency Gap value, since Democrats waste fewer votes by narrowly winning this district. In all three plans,



**Figure 18** The estimated fraction of votes won by Democrats/Republicans in each district for the congressional plans (based on past election results). Democratic fractions are shown on the bottom in blue and Republican fractions are shown on the top in red.

Democrats win many districts by overwhelming margins. The Partisan Asymmetry values in Table 1 show that all three plans are quite asymmetric; this asymmetry is evident in Figures 18a, 18b, 18c, since many Democrats are packed into a few districts instead of being more evenly distributed throughout the districts. Maintaining the four majority-minority districts may also contribute to the packing of Democrats in plans optimized for

compactness, since these districts are largely located in areas with high concentrations of Democratic voters.

Next, we examine the additional plans from Sections 6.2 and 6.3 that prioritize the Efficiency Gap and competitiveness, respectively. These plans illustrate that the Efficiency Gap and competitiveness can be substantially improved, while reasonably maintaining compactness. For example, Table 1 shows that EG1/2/3 have compactness scores only slightly higher than COMP1/2/3, but all three have Efficiency Gap values under 2%. Hence, EG1/2/3 all waste a smaller percentage of votes than COMP1/2/3 do, while maintaining comparably compact districts.

As with EG1/2/3, CMPTTV1/2/3 have similar compactness scores to COMP1/2/3; CMPTTV3 has the worst compactness score (among the competitive plans), since some of the larger districts have slightly irregular shapes. As a result of these boundary adjustments, CMPTTV1/2/3 have an average of two more competitive seats than COMP1/2/3. Figures 18g, 18h, and 18i show that these additional competitive seats result from minor shifts of Democratic/Republican voters between districts, rather than a radical redistribution of voters.

Lastly, we examine the plans from Section 6.4 that prioritize Partisan Asymmetry. These plans demonstrate that significantly improving Partisan Asymmetry requires more drastic boundaries adjustments (compared to improving the Efficiency Gap or competitiveness). For example, achieving a good (but not excellent) Partisan Asymmetry value of 0.019 in PA3 requires elongated district shapes in the Chicago area (Figure 17b). In general, improving Partisan Asymmetry requires Democratic voters to be more evenly distributed across the districts; districts in the Chicago area tend to be long or convoluted in an effort to reach a more politically diverse collection of voters. PA1/2 are more compact than PA3, but they have slightly worse Partisan Asymmetry values (Table 1). Figures 18j, 18k, and 18l show that PA1/2 have slightly more asymmetric vote-share distributions than PA3. PA1/2/3 demonstrate that Partisan Asymmetry can be moderately improved while maintaining somewhat reasonable district shapes.

From the compact, Efficiency Gap, competitive, and Partisan Asymmetry plans, we conclude there are multiple options for Illinois congressional district plans to improve partisan fairness while satisfying constitutional requirements and maintaining compactness. Illinois's political geography, combined with maintaining four majority-minority districts,

---

can cause plans optimized for compactness to have pro-Republican biases; however, the Efficiency Gap can be significantly improved and the number of competitive districts can be increased without sacrificing compactness. Partisan Asymmetry can be moderately improved, but this improvement tends to require more convoluted district shapes. Overall, congressional district plans with small Efficiency Gap values or many competitive districts would strike a balance between partisan fairness, compactness, and constitutional requirements.

### **7.1. Limitations**

The district plans constructed for this report provide insight into how political geography, maintaining majority-minority districts, and losing a congressional seat can impact Illinois congressional redistricting. However, there are limitations related to the data used to construct the plans; these limitations impact the optimization algorithm’s ability to fully consider all possible district plans. Once these limitations are considered, the 12 congressional plans in this report could serve as viable plans for Illinois.

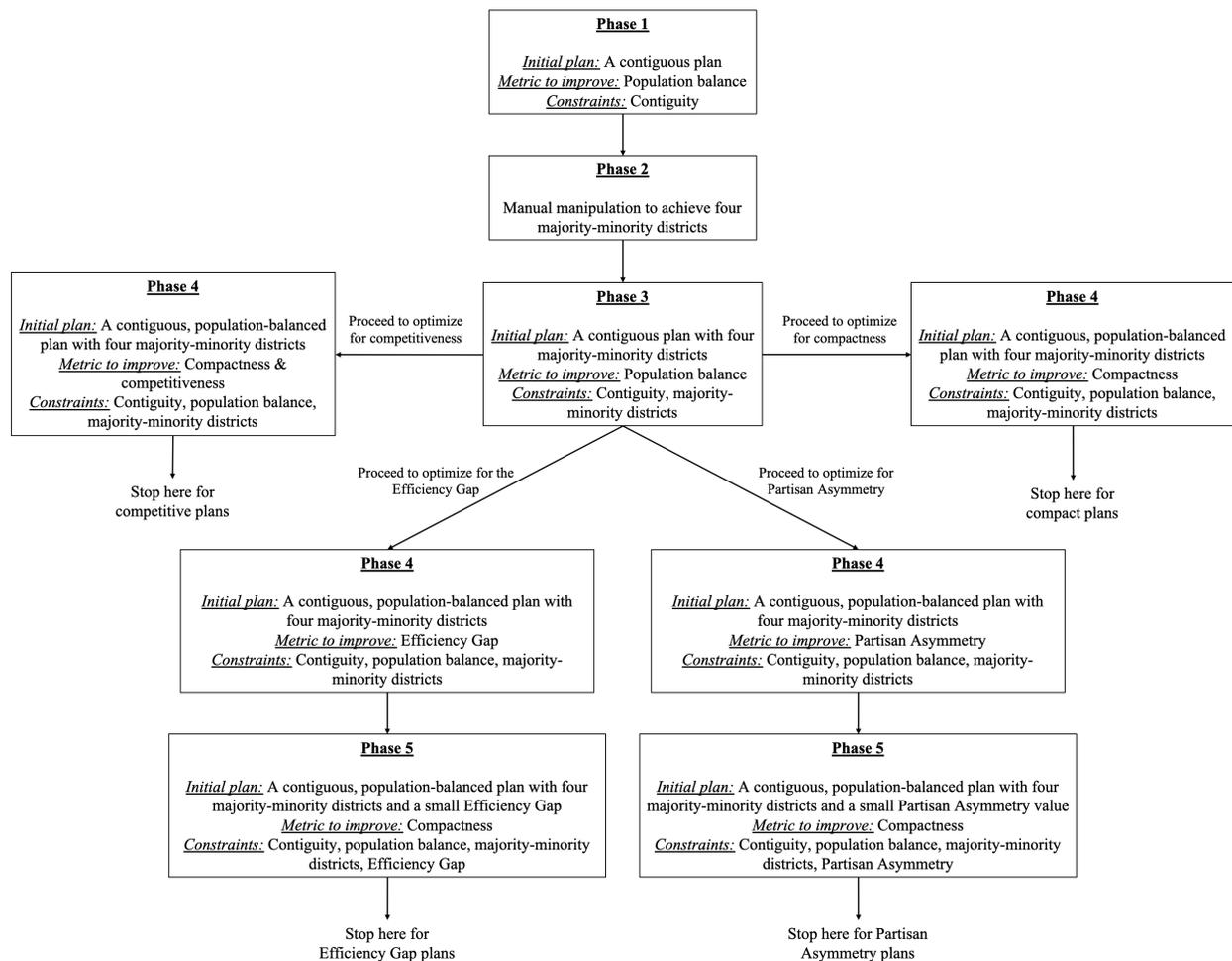
First, we construct district plans with census tracts, rather than census blocks. Although we enforce a strict population balance requirement using tracts, single-person population balance is not achieved. Therefore, the district plans in this report would require manual adjustment to achieve single-person population balance.

As discussed in Section 5.1, we only use election data from 2016, rather than data from multiple years. If voting behavior from 2016 differs substantially from voting behavior in other years, a different set of data could alter the metric values from Table 1, and possibly change what metric values are achievable for Illinois plans. Section 5.1 also discusses how we distribute precinct-level election data proportionally to census blocks/tracts; this assumes that Democratic and Republican voters are spread evenly throughout the voting precincts, which might not be the case. Lastly, Section 5.1 mentions that we use population/demographic estimates from the 2019 American Community Survey, since the 2020 population/demographic data are not yet available. Shifts in population could affect the location of districts, and changes in minority populations could affect the location or number of majority-minority districts.

## Appendix A: Additional Technical Details

In this appendix we discuss some of the technical details for creating district plans with the optimization algorithm. As mentioned in Section 4, the algorithm we use is based on a method from DeFord et al. (2019). Their paper fully explains the mechanics behind how to alter the boundary between two districts in each step of the algorithm. While their goal is to create a large sample of legal district plans for statistical analysis, our goal is to iteratively find better and better plans (with respect to some fairness metric) until there is no opportunity for significant improvement.

All experiments are run on a 3.10 GHz Core i5 2400-CPU machine with 8 GB of RAM. The algorithm steps from Section 4 are applied in multiple phases; these phases are distinguished by the initial plan the algorithm uses, the metric the algorithm improves, and the redistricting constraints the algorithm enforces. Note that the basic steps of the algorithm from Section 4 do not change between phases. Figure 19 outlines these phases and the following paragraphs provide additional details.



**Figure 19** A flowchart for the optimization algorithm phases used to construct district plans. The algorithm first optimizes population balance and creates majority-minority districts, then can proceed to optimize a particular fairness metric.

---

To create the congressional district plans, we begin with a randomly generated contiguous plan. This contiguous plan is generated by first dividing the entire state into two contiguous districts, then recursively dividing the most populated district in two until 17 districts are obtained (DeFord et al. 2019). Next, we optimize this plan for population balance (this is Phase 1 in Figure 19); the algorithm transitions between contiguous plans with smaller and smaller population deviations until 0.5% population balance is satisfied. The algorithm alternates between two methods to choose which two districts to modify during an iteration. For the first method, the algorithm first chooses the district with the largest population deviation, then chooses a random neighboring district. For the second method, the algorithm first chooses a district at random, then chooses a random neighboring district. We alternate between these methods to prevent the algorithm from getting stuck in a local minimum; improving population balance throughout the state creates more opportunities to shift population to/from the district with the largest population deviation. Achieving population balance takes between 400 and 800 iterations (approximately three hours).

We initially collect three plans that satisfy population balance; these plans are analyzed with demographic data to determine how many majority-minority districts they contain. The plan that is closest to containing four majority-minority districts is manually adjusted until four majority-minority districts are achieved (this is Phase 2 in Figure 19). We optimize this modified plan for population balance again (since manual adjustment disrupts population balance) and collect three new plans that a) satisfy 0.5% population balance, and b) have four majority-minority districts (this is Phase 3 in Figure 19). These three plans serve as initial plans for the remaining experiments.

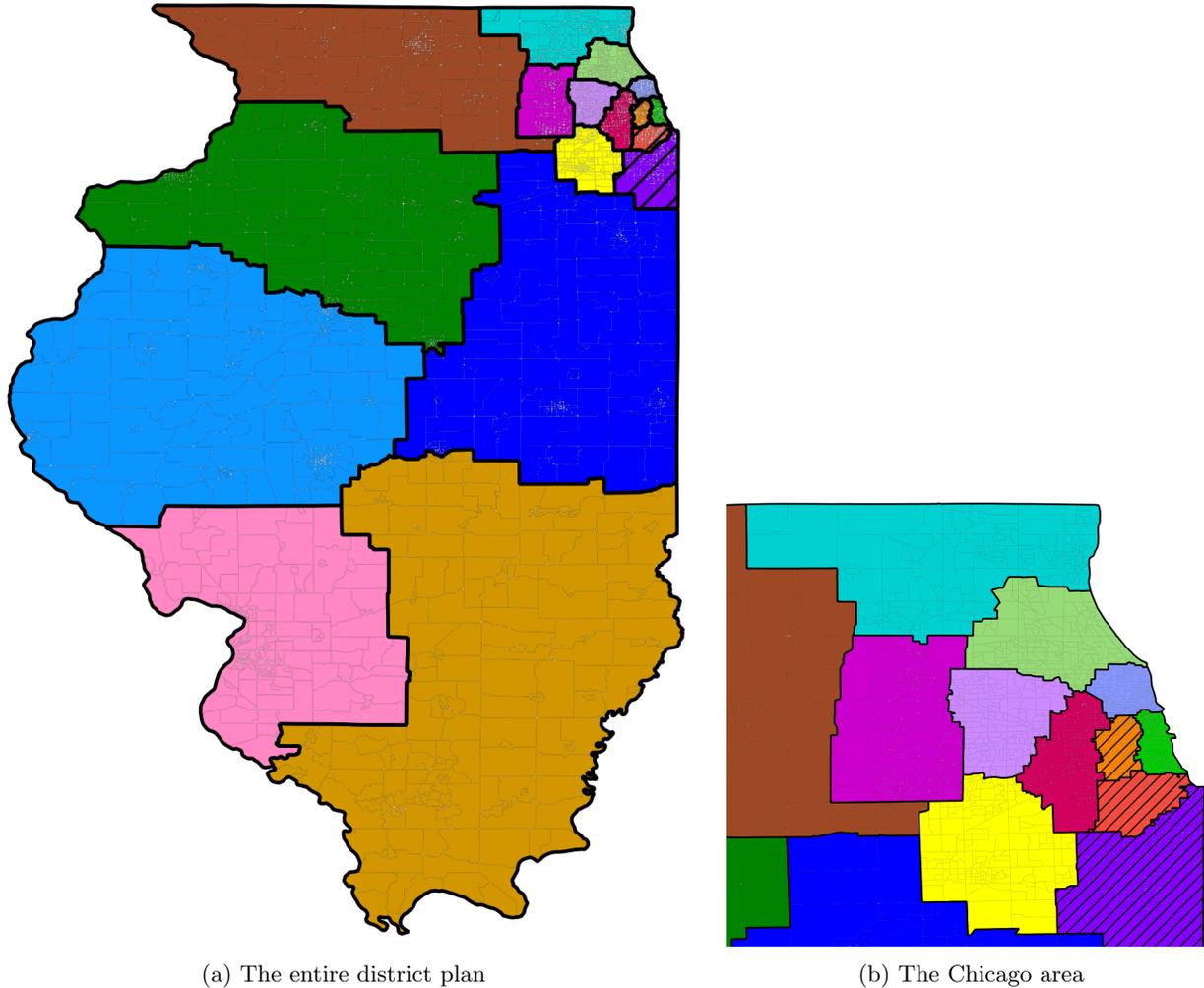
First, we optimize plans solely for compactness (this is the appropriate Phase 4 in Figure 19). The algorithm begins with the population-balanced plans, then transitions between contiguous, population-balanced plans with better and better compactness scores until the the scores appear to plateau. For these plans, and for the remaining experiments, the algorithm chooses which two districts to modify at each iteration in the following manner. First, the districts are listed in a random order. At each iteration, the algorithm chooses the next district in this list, then chooses a random neighboring district. When the algorithm has completed enough iterations to finish the list (i.e., has completed a *cycle*), a new list of districts is created, in a new random order. Cycling through the districts ensures that all areas of the state are changing at the same pace. Improving compactness takes roughly 100-150 cycles (approximately 20 hours).

Next, we optimize plans for the Efficiency Gap (this is the appropriate Phase 4 in Figure 19). The algorithm begins with the population-balanced plans, then transitions between contiguous, population-balanced plans that gradually improve the Efficiency Gap. The algorithm is run until the Efficiency Gap falls below a 2% threshold. Once the threshold is achieved, the algorithm optimizes the plans for compactness, while maintaining an Efficiency Gap value below the threshold (this is the appropriate Phase 5 in Figure 19). Improving the Efficiency Gap takes roughly 80-100 cycles (approximately eight hours), then improving compactness takes roughly 100-150 cycles. We optimize plans for Partisan Asymmetry in the same manner described for the Efficiency Gap (using the appropriate Phases 4 and 5 in Figure 19); the thresholds we use for Partisan Asymmetry are 0.02, 0.025, and 0.030. Improving Partisan Asymmetry takes roughly 80-100 cycles (approximately eight hours), then improving compactness takes roughly 100-150 cycles.

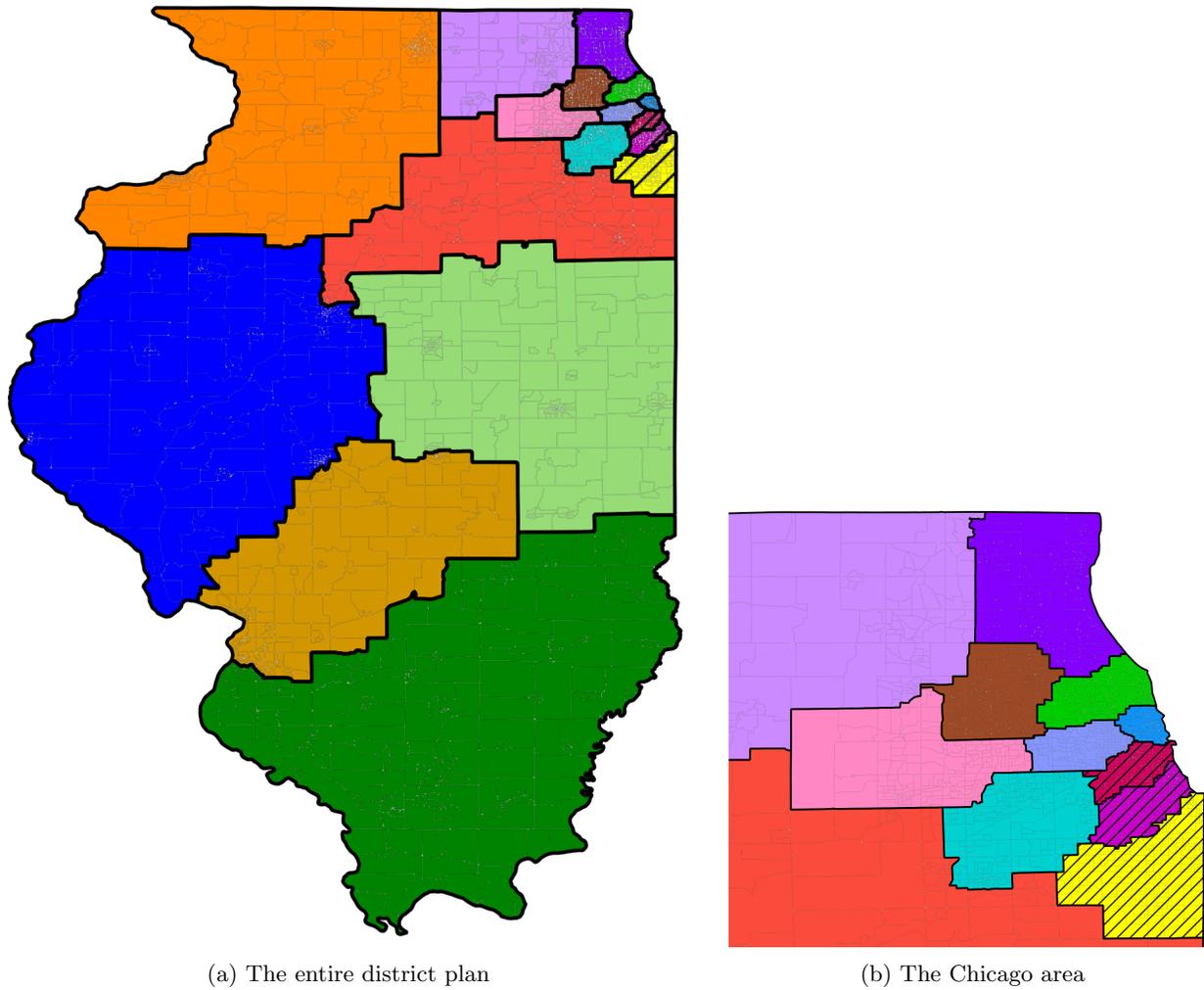
Lastly, we optimize plans for competitiveness (this is the appropriate Phase 4 in Figure 19). In contrast to the Efficiency Gap and Partisan Asymmetry plans, we improve competitiveness and compactness simultaneously. The algorithm begins with the population-balanced plans, then transitions between contiguous, population-balanced plans with better and better compactness scores. However, if the algorithm creates a competitive district during an iteration, that district remains competitive for all future iterations. Therefore, as compactness improves, the number of competitive districts also increases. Improving competitiveness and compactness simultaneously takes roughly 100-150 cycles (approximately 20 hours).

## Appendix B: Compact Plans - Three Majority-Minority Districts

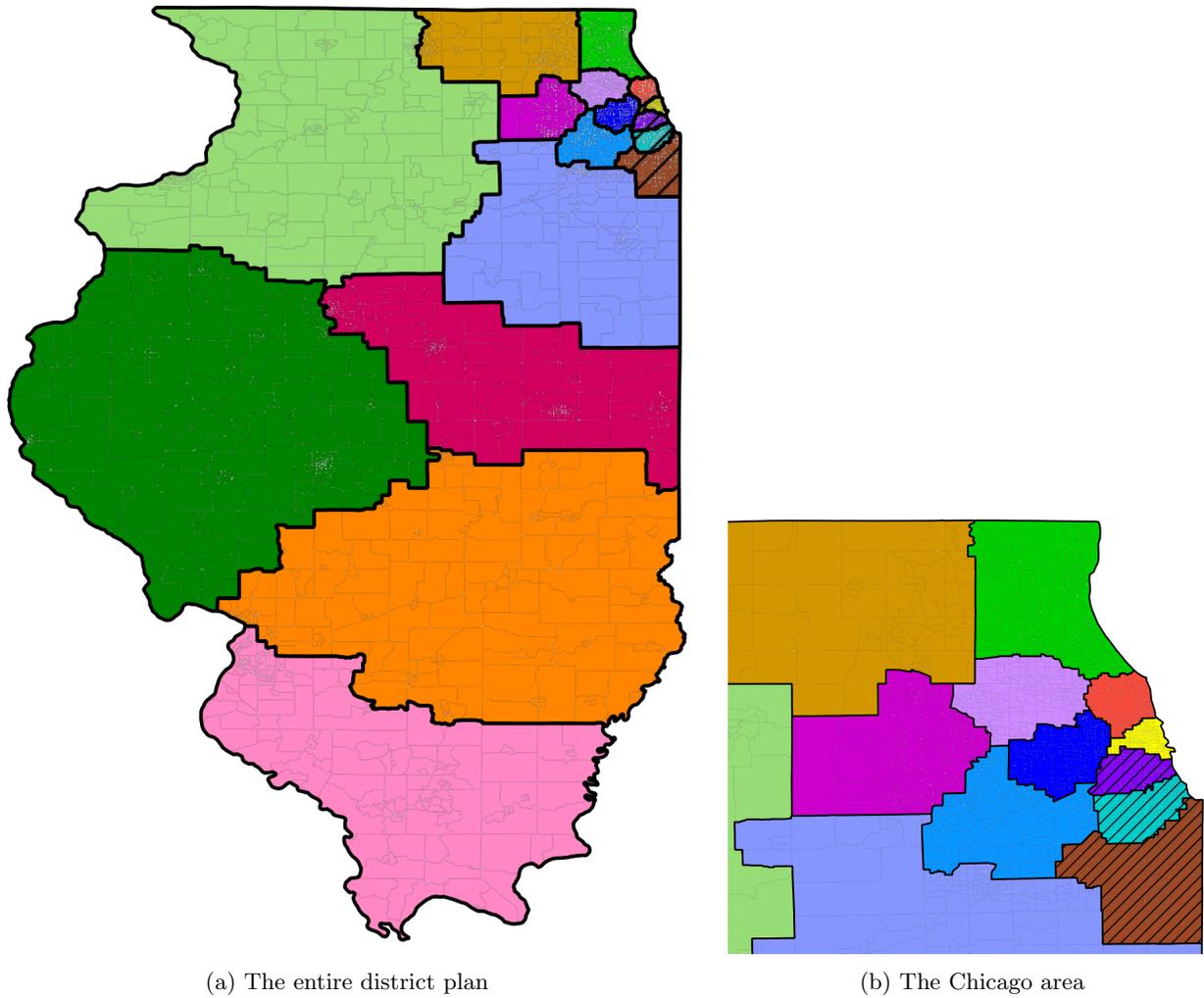
This appendix displays district plans optimized solely for compactness while maintaining three majority-minority districts (instead of four, as in Section 6). Figures 20b, 21b, and 22b below show more compact districts in the Chicago area than Figures 6b, 7b, and 8b in Section 6.1; hence, maintaining four majority-minority districts may require some irregular district shapes.



**Figure 20** A congressional plan optimized for compactness (while maintaining three majority-minority districts), with a closer view of the Chicago area. District boundaries are shown in black, and the three majority-minority districts have black stripes.



**Figure 21** A congressional plan optimized for compactness (while maintaining three majority-minority districts), with a closer view of the Chicago area. District boundaries are shown in black, and the three majority-minority districts have black stripes.



**Figure 22** A congressional plan optimized for compactness (while maintaining three majority-minority districts), with a closer view of the Chicago area. District boundaries are shown in black, and the three majority-minority districts have black stripes.

## References

- American Community Survey (2019) ACS demographic and housing estimates. URL <https://data.census.gov/cedsci/table?t=Race%20and%20Ethnicity&g=0400000US17,17.140000&y=2019&tid=ACSDP5Y2019.DP05>.
- Ballotpedia (2015) Redistricting in Illinois. URL [https://ballotpedia.org/Redistricting\\_in\\_Illinois](https://ballotpedia.org/Redistricting_in_Illinois).
- DeFord D, Duchin M, Solomon J (2019) Recombination: A family of Markov chains for redistricting. *arXiv preprint, arXiv:1911.05725* .
- Grofman B (1983) Measures of bias and proportionality in seats-votes relationships. *Political Methodology* 9(3):295–327.
- Grofman B, King G (2007) The future of partisan symmetry as a judicial test for partisan gerrymandering after LULAC v. Perry. *Election Law Journal* 6(1):2–35.
- Hirano S, Snyder J (2012) Primary elections and political accountability: What happens to incumbents in scandals? *Quarterly Journal of Political Science* 7(4):447–456.
- Massachusetts Historical Society, The gerry-mander: A new species of monster which appeared in Essex South District in Jan. 1812. URL <https://www.masshist.org/database/1765>.
- McCarty N, Poole KT, Rosenthal H (2009) Does gerrymandering cause polarization? *American Journal of Political Science* 53(3):666–680.
- NCSL (2019) Redistricting criteria. URL <https://www.ncsl.org/research/redistricting/redistricting-criteria.aspx>.
- OpenPrecincts (2020) Illinois. URL <https://openprecincts.org/il/>.
- Stephanopoulos N, McGhee E (2015) Partisan gerrymandering and the efficiency gap. *The University of Chicago Law Review* 82(2):831–900.
- Tapp K (2018) Measuring political gerrymandering. *arXiv preprint, arXiv:1801.02541v2* 1–22.
- US Census Bureau (2010) Tiger/line shapefiles. URL <https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2010.html>.
- US Census Bureau (2020) Tiger/line shapefiles. URL <https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html>.
- Young H (1988) Measuring the compactness of legislative districts. *Legislative Studies Quarterly* 13(1):105–115.