GS-20 - Aggregation of Spatial Entities and Legislative Redistricting

The partitioning of space is an essential consideration for the efficient allocation of resources. In the United States and many other countries, this parcelization of sub-regions for political and legislative purposes results in what is referred to as districts. A district is an aggregation of smaller, spatially bound units, along with their statistical properties, into larger spatially-bound units. When a district has the primary purpose of representation, individuals who reside within that district make up a constituency. Redistricting is often required as populations of constituents shift over time or resources that service areas change. Administrative challenges with creating districts have been greatly aided by increasing utilization of GIS. However, with these advances in geospatial methods, political disputes with the way in which districts increasingly snare the process in legal battles often centered on the topic of gerrymandering. This chapter focuses on the redistricting process within the United States and how the aggregation of representative spatial entities presents a mix of political, technical and legal challenges.

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Topic Description:

1. Definitions

Compactness: the area a district occupies in relation to its center.

Contiguity: a district where all parts are connected to each other.

Cracking: dividing a group of constituents with the same characteristics into more than one district with the result of diluting their representation.

Gerrymandering: drawing a district shape with intentional bias (benefiting one party over another)
Packing: the act of grouping constituents into districts, with the effect of diluting their overall influence within the final district plan.
Zone arrangement effect: change in constituent district plan influence caused solely by a change in the way districts are drawn within the same district plan parameters.
Scale effect: variation in the constituent characteristics caused by using fewer and larger geographic units for analysis.

2. The District Plan Process

The process of districting (and redistricting) usually consist of combining existing geographically-bounded places to create a newly defined administrative boundary (voting tabulation districts can be an exception to this process of aggregation, covered below). The workflow for creating a district plan is illustrated below. This flowchart illustrates the approaches to districting used by popular GIS-based districting tools such as Esri's ArcGIS Districting tool (Esri, 2011) and Caliper's (2018) Maptitude tool. The flowchart below generalizes the districting process to seven steps (Fig. 1):

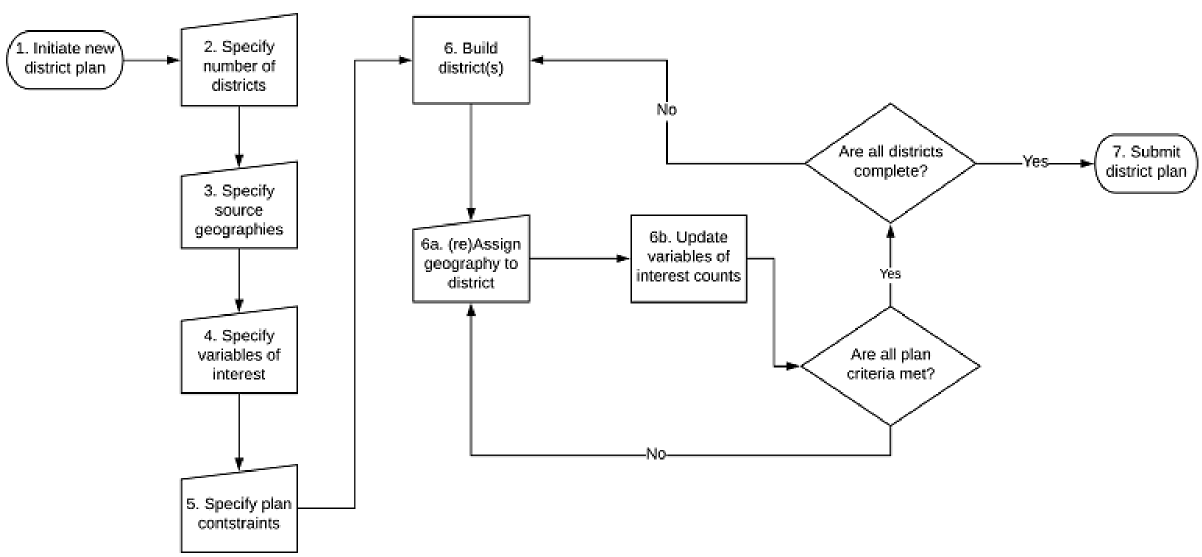

Figure 1. The District Plan Process

2.1 Initiating District Plans

districts such as occurs following the decennial census when legislative boundaries within the U.S. are re-districted. However, an entirely new district plan may be created to accommodate new community resources (e.g., the building of a new school in a newly developed community). A districting plan, $\mathcal{D}$, is made up of the geographically defined areas of districts, d_i or $\mathcal{D} = \{d_1, \ldots, d_n\}$ where *d* make up the individual district boundaries for 1 to *n* number of districts within a given plan. The number of districts specified (*step 2*) will depend on type underlying geography and type of districting plan. For instance, in the U.S. state of Florida, there were 23 congressional districts (seats) during the 2000 redistricting cycle. However, with population growth in the preceding decade, Florida was allotted 25 congressional districts following the 2010 redistricting cycle.

2.2 Source Geographies

Source geographies for districts (*step 3*) typically depend on census-defined shapes (delimited areas representing populations). Census shapes, such as tracts, cover large areas at a small cartographic scale. More precise polygonal coverages of smaller area units are also recorded such as a census block. Also relevant are Voting (tabulation) Districts or VTDs. VTDs can refer to a variety of areas, such as election districts, precincts, legislative districts, or wards, established by states and local government and are establish on a per state basis (U.S. Census Bureau, 2018).

2.3 Variables of Interest

Those charged with building districts do so by specifying variables of interest (*step 4*) and arranging source geographies accordingly. Ideally, the selection of these variables is motivated by principles of districting that favor the constituents' interest over those who draw the districts (Edwards et al., 2017). For this reason, when building districts, underlying population characteristics within the source geographies are of central importance. To accomplish this task, district builders observe variables that indicate enumerated counts by census geography and other demographic characteristics. For instance, when building a middle school district, aggregated counts of appropriately aged residents (e.g., ages 11-13) per source geography is monitored at each aggregation. Moreover, an essential factor in the aggregating of statistical areas is what Openshaw (1983) termed the Modifiable Areal Unit Problem or MAUP. The MAUP consists of two separate but related effects that those charged with districting consider: the **scale** and the **zone arrangement effect**.

2.3.1 Scale effect

Because of the varying population characteristics of underlying source geographies, it is essential to be aware of the **scale effect** when building districts (de Smith et al., 2018; Openshaw, 1977; 1983). The scale effect manifests as a problem for districting because statistical variation occurs when source geographies aggregate into fewer and larger units for analysis. To illustrate how this effect can manifest within the districting process consider the below hypothetical community of X's and Os (Fig. 2).

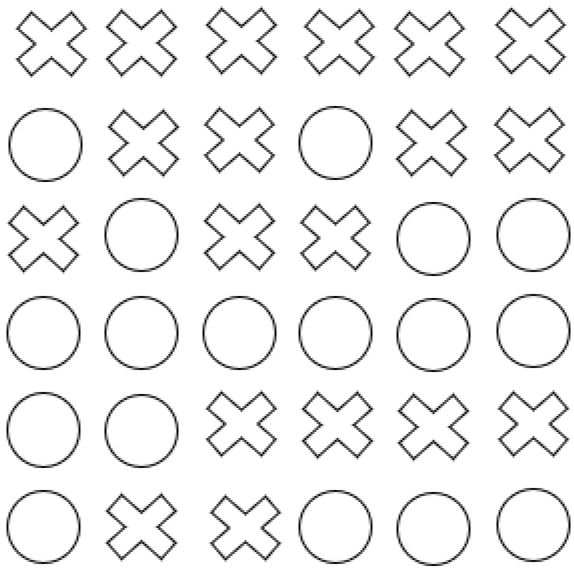

Figure 2. Community of X's and O's (6x6).

With an initial district plan of 9 districts each containing a population of 4 individuals, we can illustrate how X's gain majority control of the most districts. The resulting district plan implies that in any majority voting situation the X's will have a higher likelihood of controlling a political agenda (Fig. 3). This example assumes that each constituent gets one vote that counts equally within the district plan.

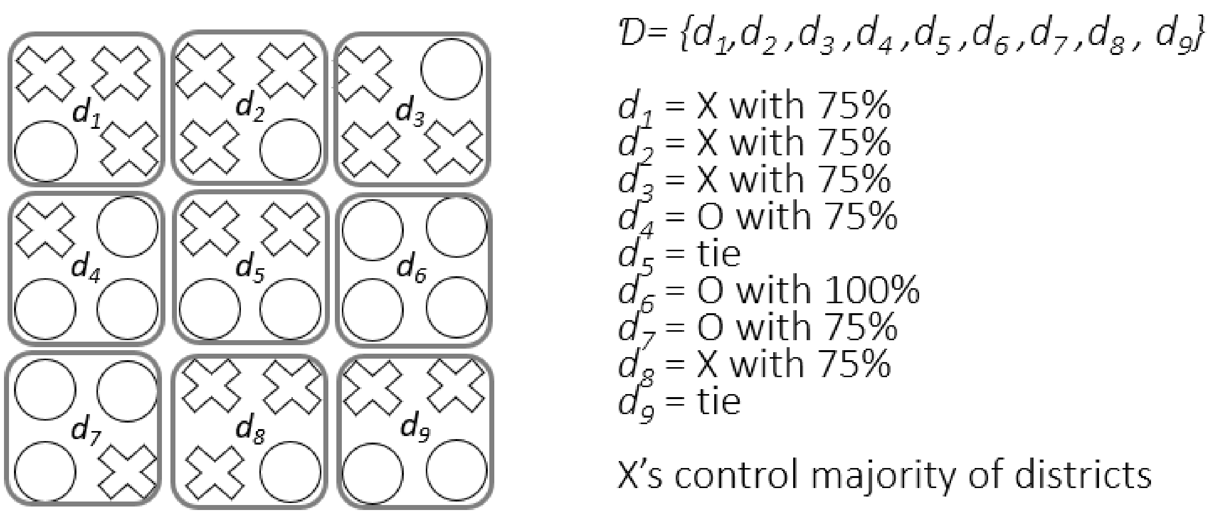

Figure 3. X's Control Majority of Districts

However, if we reduce the number of districts and increase the number of constituents within those districts, we can illustrate the scale effect (Fig. 4). Note here the level of aggregation has gone up and the governing majority has shifted to the party of O's.

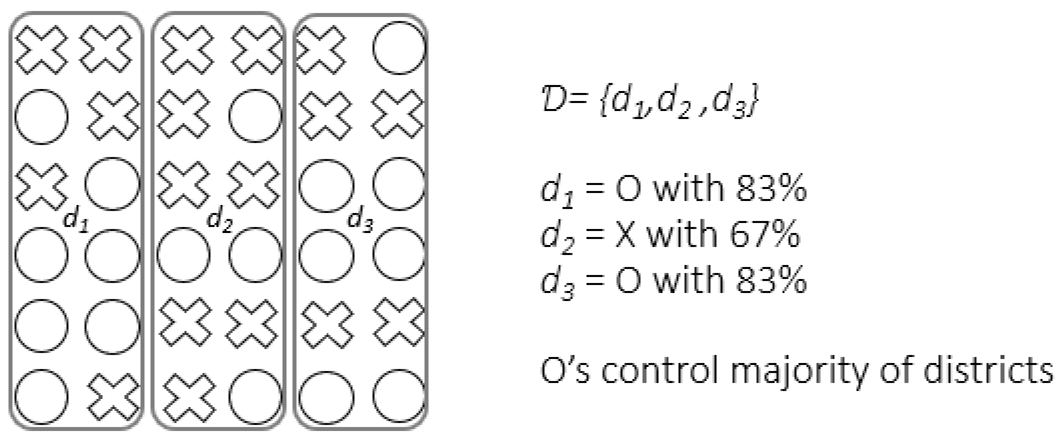

Figure 4. O's Control Majority of Districts

2.3.2 Zone arrangement effect

If we hold the number of districts and populations within those districts constant but change the way in which we draw the districts, we can achieve the zone arrangement effect (de Smith et al., 2018; Openshaw 1988). To illustrate how the zone arrangement effect can manifest itself within the districting process consider the below hypothetical community of X's and O's adapted from a scenario provided in Ingraham (2015). The district plan to the right illustrates perfectly proportional representation, where each community gets a district proportional to its population size within the community.

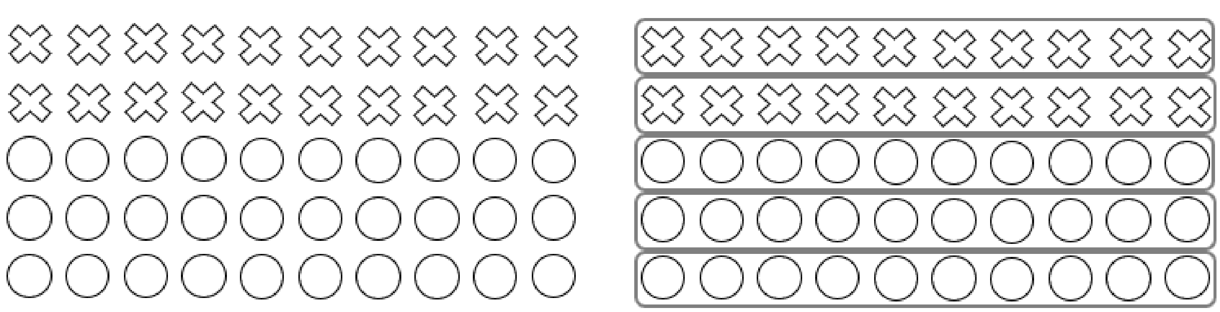

Figure 5. Community of X's and O's (5x10) and Proportional Districts

To illustrate the zone arrangement effect, we can consider two different zonal arrangements manifestations that are specific to the legislative districting process. **Cracking** is the popular terminology for the act of dividing groups of constituents with the same characteristics into more than one district with the result of diluting representation of that same group (Levitt, 2010; Stephanopoulos & McGhee, 2015). The zonal arrangement effect of cracking is illustrated in Fig. 6 where the O's obtain majority control within the district plan.

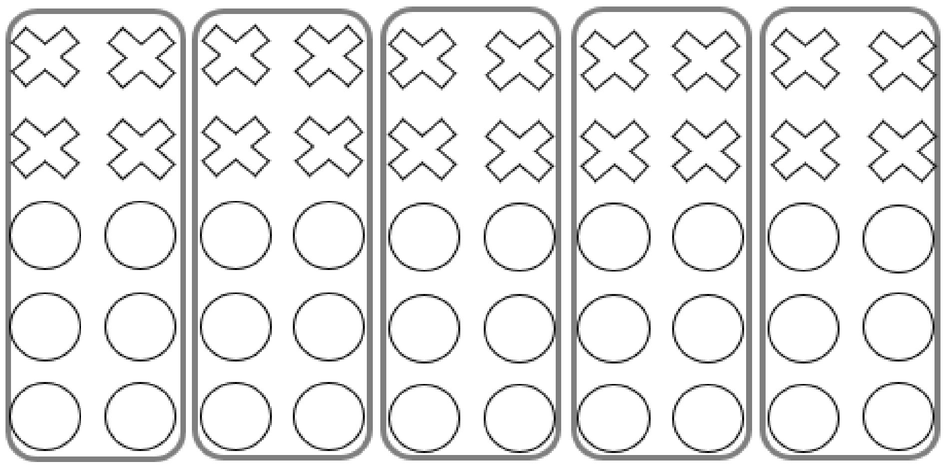

Figure 6. O's Control Majority of Districts

The practice of cracking refers to electoral districts where potential votes within a minority constituency are the variable of interest. **Packing** is an act of grouping constituents into districts, with the effect of diluting their overall influence within the final district plan. Fig. 7 illustrates an example of packing where a community minority of X's gains majority control of the districts within the plan.

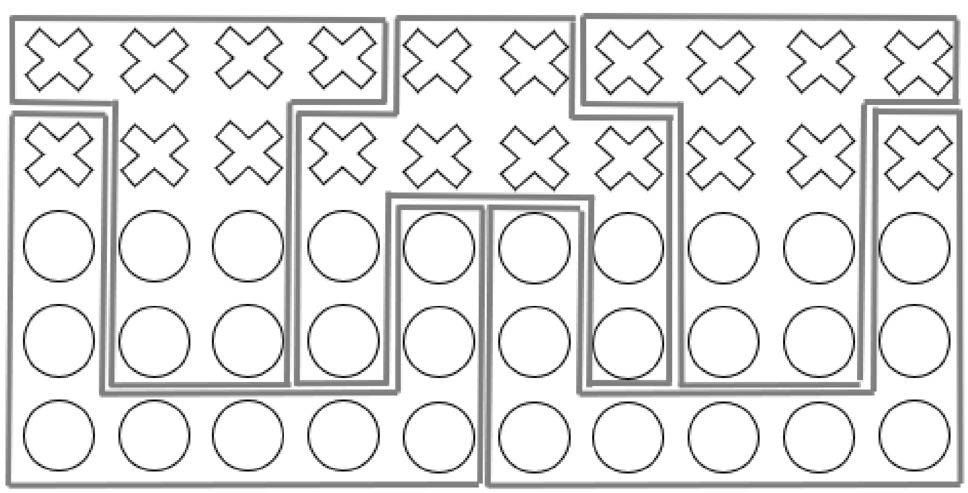

Figure 7. X's Control Majority of Districts

2.4 Plan Criteria

Plan criteria (*step 5*) determine requirements for the specific variable of interest and how those variables are distributed across districts. Further, plan criteria/constraints can be further broken out into critical issues, such as legal and political constraints, which in practice may eclipse the other steps within the districting process in terms of time/money. For instance, the "one person, one vote" rule that was confirmed by *Wesberry v. Sanders (1964)* requires that within U.S. congressional districts there should be approximately equal populations of constituents. But, if districting plan criteria were as simple as “one person, one vote”, redistricting would be a relatively simple process. Specifically, accounting for spatial variation of constituents is very important. For instance, plan criteria have come under scrutiny no less than 22 times by the U.S. Supreme Court since the enactment of the *Voting Rights Act* (VRA) of 1965.

The degree of discretion is allowed within the drawing of a district varies by region, constituency and plan type The more criteria there are, and the less discretion the line-drawers have, the less critical it may be to choose one set of line-drawers over another (Levitt, 2010). One criterion that has received considerable media attention is the criteria to maintain communities of interest within given district boundaries where possible. If there are multiple districts to be assigned within a plan, then the building of districts is an iterative process (*step 6*). Once all district plan criteria are satisfied, the districting process continues through to submission (*step 7*).

3. Measuring Districts

Increasing utilization of GIS has dramatically aided administrative challenges with creating districts. However, with these advances in geospatial methods, political disputes with the way in which districts are drawn increasingly snare the process in legal battles (Herron & Wiseman, 2008). Most notable is the so-called gerrymandered district, which contains intentional bias (benefiting one party over another). The term gerrymander refers to the former Massachusetts governor Elbridge Gerry (Griffith, 1907). Attempts to match the ideal of representative equitability in drawing districts is not always a simple geometric solution. Therefore, several methods for measuring districts are available. We can divide these measures of districts into two broad categories: those based on geometric shape and those that consider the population of constituents within the districts.

3.1 Based on Geometry

Traditional consideration of measurement for districts mainly has been based on geometric measures. For instance, the *U.S. Apportionment Act of 1911 (Pub. 62–5, Stat. 13)* specified that Congress consists of districts composed of contiguous and compact territory and containing an approximately equal number of inhabitants. And thought this Act set a precedence for these geometric measures, it was subsequently dropped in the *U.S. Apportionment Act of 1941*. Two of the most widely cited geometric considerations are compactness and contiguity.

3.1.1 Compactness

Compactness refers to the area a feature (e.g., district) occupies in relation to its area center. For this reason, the circle (most compact of shapes) is used for shape correspondence (Galton 2017). The most-cited measure cited in redistricting literature and expert testimony is the Polsby-Popper score first (Polsby & Popper, 1991). The simple geometric formulation of this measure is given as A/P^2, comparing the area, A, to the perimeter, P. The resulting formula is sometimes normalized as $4\pi A/P^2$ guaranteeing scores ranges from 0 to 1 (MacEachren 1985). In this measure, a district with lower values (closer to 0) less compact, as compared to a district with values closer to 1.

That compactness should be a primary goal in districting is debatable. Within U.S. electoral districts many states (following the VRA) have made the case that drawing intentionally fewer compact districts is necessary. One example of how a compactness exception works in practices is Illinois's well known "earmuffs district," which joins Hispanic communities in Chicago's North and South Sides (Stephanopoulos, 2012). Fig. 8 below illustrates the odd shape this district assumes as it attempts to maintain what the court in 1997 considered necessary to maintain a community of interest (See *King v. State Bd. of Elections 1997*).

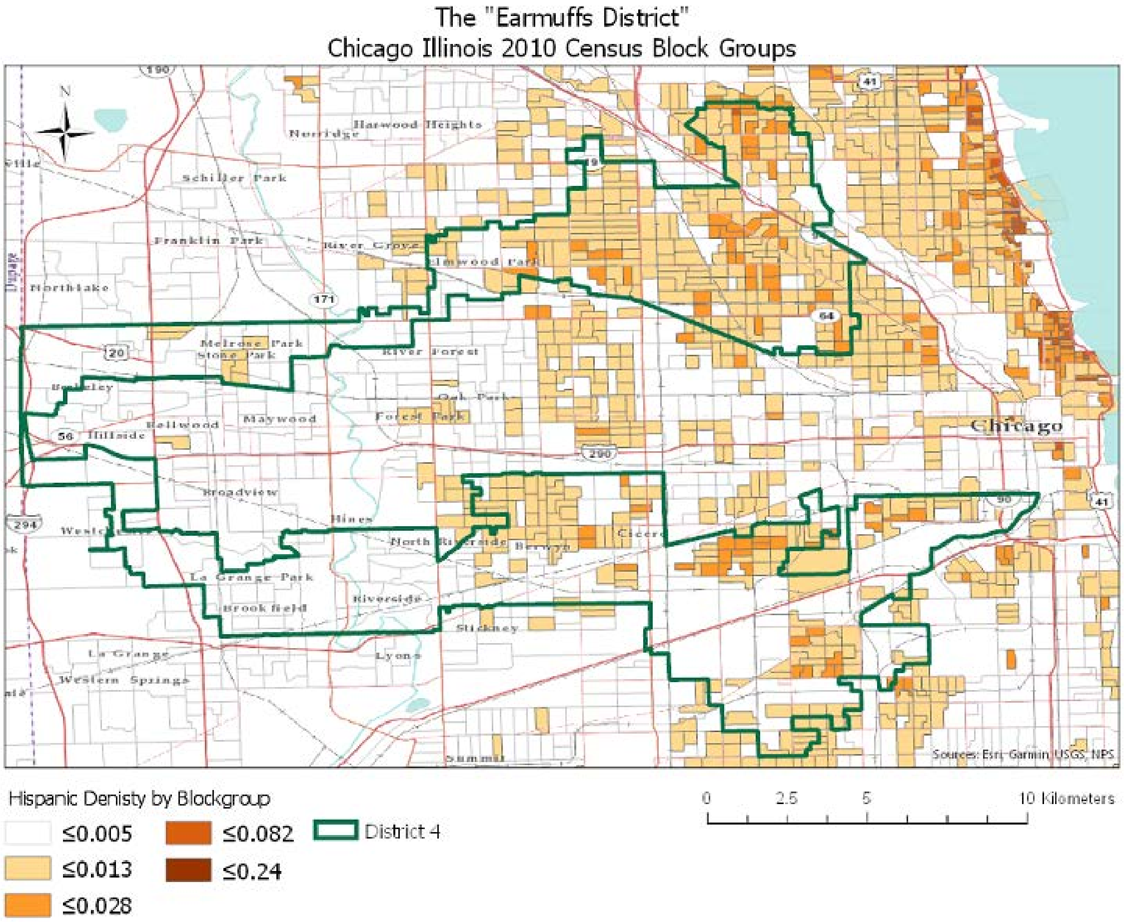

Figure 8. Illinois' 4th District, a.k.a "Earmuffs District."

3.1.2 Contiguity

The requirement of **contiguity** is a potential standard criterion for districts within a given plan. *Contiguity*means someone could go from one end of the district to the other without leaving the district (Levitt, 2010). A contiguity criterion for districts requires that all parts of a district within a given plan be connected spatially. Often the physical geography of an area challenges this requirement, such as the case in areas with bisecting waterways. Most people consider districts divided by a waterway to be contiguous if a bridge runs across the water; island districts are generally contiguous as long as the island is part of the same district as the closest mainland, as in Washington's 2nd Congressional District (Levitt, 2010)

In other cases built features of an area may be used to connect district areas. For example, in the Illinois 4th district efforts attempts to comply with the VRA have led to the two largest sections of the district being connected solely by a stretch of Interstate 294 to the west (Fig. 8). It should be noted that the VRA has recently been vacated in part 4(b) by the Supreme Court in the final ruling of *Shelby County v. Holder*(2013) regarding "preclearance" which required states with histories of racial discrimination to draw districts which are checked by the U.S. Department of Justice for discrimination.

3.2 Based on Constituents

Redistricting is often required as populations of constituents shift over time or resources that service areas change. The *U.S. Reapportionment Act of 1929 (ch. 28, 46 Stat. 21, 2 U.S.C.)* established a permanent method for apportioning 435 seats in the U.S. House of Representatives according to each census. However, many have argued that while this act which empowered the Census Bureau to make all future reapportionment determinations also opened the door for subsequent laws and political maneuvering that leads to gerrymandering (Gaughan, 2013; Stephanopoulos, 2014). For instance, the U.S. Supreme Court has ruled that partisan-focused gerrymandering in and of itself is not unconstitutional (Jacobson, 2018).

In the U.S. and other countries, it remains a complicated case to challenge a malapportioned district plan in a way that courts find acceptable (Bernstein & Duchin, 2017). Several different approaches have attempted to grapple with the complex issue of measuring potentially gerrymandered plans. Seminal work by Gelman & King (1994) proposed methods to predict probable electoral outcomes called the bias and responsiveness. Measures of bias and responsiveness can be used to show deviations from party symmetry or plans drawn to protect incumbents respectively. Later a mean-median difference approach was developed that that looks at the difference between the mean and the median of the democratic vote among all the districts within a given plan (McDonald & Best 2015). In this approach, when there is a large difference between the mean and median asymmetry in the vote distortion is indicated.

A measure that has recently been actively considered by the courts to measure potentially malapportioned districts has surfaced in the U.S. state of Wisconsin in the case of *Whitford v. Gill* (2016). Stephanopoulos & McGhee (2015) formalized this measure, which represented a pioneering effort within U.S. electoral districting. This measure, called the *efficiency gap*, measures the difference between the political parties' respective wasted votes in an election for a district, divided by the total number of votes cast within that same district. Stephanopoulos & McGhee (2015) proposed a threshold of 8 percent or greater to detect gerrymandering within state legislative electoral district plans. Even with this measure, the plaintiff in the case of *Whitford v. Gill*(2016) was not successful, and the challenge of successfully measuring gerrymandering in a way that consistently persuades courts remains.

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Learning Objectives:

- Explain the nature and causes of the Modifiable Areal Unit Problem (MAUP)

- Explain the two modifiable areal unit effects that can occur during the districting process.
- Discuss the potential pitfalls of using regions to aggregate geographic information (e.g., census data) Know the definition and origins of the term gerrymandering.
- Demonstrate the relationship between district size (resolution/support) and patterns in aggregate data
- Demonstrate how changing the geometry of regions changes the data values (e.g., voting patterns before and after redistricting

Additional Resources:

Bycoffe, A., Koeze, E., Wasserman, D. & Wolfe, J. (2018). The Atlas of Redistricting. Available via FiveThirtyEight at https://projects.fivethirtyeight.com/redistricting-maps

The U.S. Census Bureau's Decennial Census of Population and Housing. Available at https://www.census.gov/rdo/

Related Topics:

- Scale and Generalization

Keywords:

- compactness
- contiguity
- gerrymandering
- MAUP
- packing
- aggregation
- generalization and aggregation
- redistricting

This Topic is also available in the following editions: DiBiase, D., DeMers, M., Johnson, A., Kemp, K., Luck, A. T., Plewe, B., and Wentz, E. (2006). Aggregation of Spatial Entities. *The Geographic Information Science & Technology Body of Knowledge.* Washington, DC: Association of American Geographers. (2nd Quarter 2016, first digital).