TEXAS TECH

UNIVERSITY®

IEM 3311 & 5318 SEMESTER PROJECT – FINAL REPORT

Team Name: Redistricting Solutions

Team Members: Nirmitkumar Shah, Devansh Shah (Student IDs: R11843484, R11853640)

Executive Summary

The state under consideration for redistricting is Alabama, which has maintained the same seven congressional districts since 1973. As of 2010 and 2020, Alabama continues to have seven congressional districts, with unchanged district lines for over four decades. The key criteria for these district maps include contiguity and the requirement for approval. Notably, Alabama's redistricting adheres to strict criteria, as even a 1% population deviation can render the redistricting unconstitutional.

Alabama's counties have been redistributed into seven districts, with each district meeting specific demographic and geographic considerations. District 1, the smallest district, encompasses counties such as Cleburne, Tallapoosa, Crenshaw, Calhoun, Elmore, Randolph, Clay, Cherokee, Lee, Chambers, Lowndes, Talladega, Autauga, and Macon, totaling a population of 714,963. District 2, the largest district with a population of 720,310, includes Jefferson, Bibb, Hale, and Perry counties. District 3, with a population of 717,488, comprises Clarke, Washington, Mobile, Monroe, Baldwin, and Choctaw counties. District 4, with a population of 718,247, encompasses Shelby, Dallas, Pickens, Walker, Chilton, Marengo, Greene, Fayette, Tuscaloosa, Wilcox, Coosa, Sumter, and Winston counties. District 5, totaling 719,832 people, includes Lawrence, Morgan, Etowah, DeKalb, Marshall, Blount, Jackson, St. Clair, and Cullman counties. District 6, with a population of 717,940, consists of Lauderdale, Madison, Lamar, Franklin, Colbert, Limestone, and Marion counties. Finally, District 7, with 715,499 people, encompasses Barbour, Geneva, Dale, Houston, Russell, Conecuh, Montgomery, Coffee, Covington, Henry, Butler, Escambia, and Pike counties. This redistricting plan was derived from a minimization problem.

Introduction

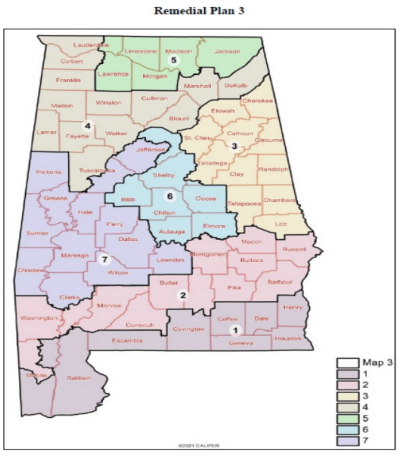
In response to the dynamic demographic shifts unveiled by the 2020 Census, this project embarks on a strategic mission to formulate optimal congressional redistricting plans for the state of Alabama. The primary objective is to recalibrate electoral boundaries to accurately reflect the evolving population distribution and uphold the principles of democratic representation. Leveraging cutting-edge technologies and a sophisticated optimization model, our endeavor seeks to create a blueprint that aligns with federal and state guidelines while addressing critical criteria such as population balance, contiguity, equal representation, compactness, and the preservation of county integrity.

Project Objectives

The pivotal goal of this initiative is to craft congressional districts that not only comply with regulatory frameworks but also stand as pillars of fairness, equity, and inclusivity. As we delve into the intricate task of redistricting, several key objectives guide our efforts:

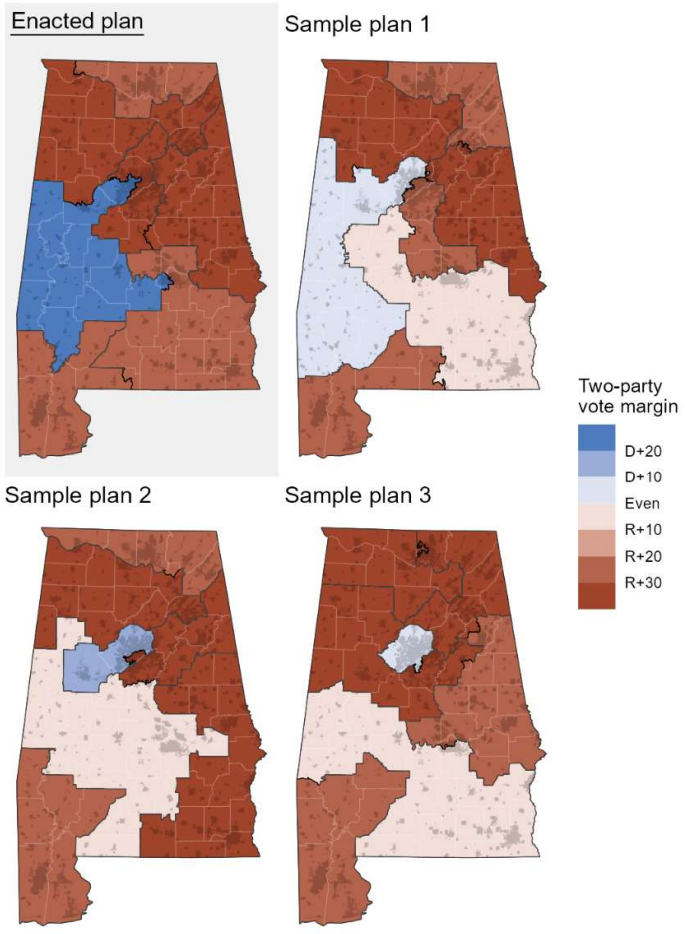
1. Population Balance:

A fundamental tenet of this project is to ensure an equitable distribution of population across congressional districts. By meticulously analyzing the demographic nuances revealed in the 2020 Census, our optimization model aims to counteract any imbalances, fostering a more representative electoral landscape.



2. Contiguity:

Geographical contiguity is a cornerstone of effective representation. Our redistricting plans prioritize contiguous districts, promoting logical and connected boundaries that enhance both administrative efficiency and voter engagement.



3. Equal Representation:

In the pursuit of democratic ideals, we are committed to achieving equal representation for all citizens. Our optimization model scrutinizes demographic data to prevent any bias or dilution of voting power, particularly focusing on minority communities to ensure their voices are heard and respected.

4. Compactness:

The geographic compactness of districts is integral to the visual and practical coherence of electoral boundaries. Through careful consideration of spatial arrangements, we strive to create compact districts that are geographically sensible and promote a clear understanding of electoral geography.

5. County Preservation:

Respecting county boundaries is vital for preserving local identities and administrative cohesion. Our redistricting plans aim to minimize disruption to existing county lines while adhering to population and representation considerations.

Methodology

criteria for Congressional Redistricting: Balancing Equity and Representation

In the intricate landscape of congressional redistricting, the adherence to a set of well-defined criteria is paramount to uphold democratic values and ensure an inclusive representation of the population. This project, responding to both Federal and State directives, meticulously incorporates a range of criteria to guide the creation of optimal congressional districts for Alabama following the release of the 2020 Census results.

Federal Criteria

1. Population Balance:

At the federal level, the guiding principle is the pursuit of population balance. Each congressional district is meticulously crafted to have approximately the same population, thereby fostering equitable representation. This commitment to demographic parity ensures that the fundamental democratic principle of "one person, one vote" is upheld, preventing any undue concentration or dilution of political influence.

2. Contiguity:

Ensuring the contiguity of districts is a federal imperative, aiming to prevent the fragmentation of electoral territories. Districts must be contiguous, devoid of isolated segments, to maintain logical and connected boundaries. This criterion contributes not only to administrative coherence but also to the engagement and understanding of voters within each district.

3. Equal Representation:

The foundational "one person, one vote" principle takes center stage in the pursuit of equal representation. This federal criterion emphasizes the need for fair and proportionate representation, guarding against any distortion that might compromise the democratic ideals of the electoral process.

State Criteria

1. Compactness:

In alignment with state guidelines, Alabama places a premium on compact district shapes to curb gerrymandering tendencies. Compact districts, with clear and sensible boundaries, not only contribute to the visual coherence of electoral maps but also serve to mitigate the potential manipulation of district lines for partisan advantage.

2. Preservation of Counties:

Respecting local administrative units, congressional districts in Alabama are designed to minimize the separation of counties wherever possible. This criterion recognizes the importance of maintaining the integrity of county boundaries, preserving local identities, and facilitating effective governance.

3. Political Fairness:

Implicit in the state criteria is a commitment to political fairness, denouncing partisan gerrymandering. By striving for equal representation and avoiding undue favoritism toward any political party, the redistricting process in Alabama aims to fortify the democratic foundation of fair and competitive elections.

In synthesizing these federal and state criteria, the overarching goal is to construct congressional districts that not only comply with legal standards but also embody the principles of fairness, equity, and transparent representation. Through a meticulous integration of demographic data, geographic considerations, and the outlined criteria, this redistricting endeavor aspires to set a benchmark for democratic excellence in electoral processes.

Integer Programming Model

OR Model In Words

● Indices:

○ i is the county i ∈ {1, 2, ..., n}

○ j is the district j ∈ {1, 2, ..., k}

● Parameters:

○ n= # of counties in Alabama7

○ k= # of districts desired

○ L= lowest district population

○ U= highest district population

● Variables:

○ x = 1 when county i ∈ {1, 2, …, n} is assigned to district j ∈ {1, 2, …, k} ; 0ij

otherwise

○ p = population of each district ii

○ f = flow across arc [i,j,v] that is sent from source/ root vijv

● Objective Function:

○ Objective is to minimize the moment of inertia: sum (d^2 * p * x over all i and j =w)ij

■ This equation uses the districts as bodies with a centroid. The centroid can

be at j or another location i, or some distance d from the centroid j. “The ij mass of the parcel is its population” (Two MIPs for redistricting)

Problem Statement: Navigating the Complexities of Redistricting

The redistricting process in Alabama emerges as a multifaceted challenge, demanding a delicate balance between federal demographic regulations and state constitutional limitations. At its core, the endeavor strives to reconcile divergent requirements to yield a redistricting outcome that is not only legally sound but also embodies the principles of fairness, geographic coherence, and representative democracy.

Complexity of Balancing Federal and State Dynamics

The challenge at hand lies in harmonizing the intricate dance between federal mandates and state-level constitutional restrictions. Federal rules demand equitable population distribution, contiguity, and equal representation, while Alabama's state constitution introduces criteria such as compactness, county preservation, and a nuanced consideration for political fairness. Successfully navigating this intricate terrain requires a nuanced understanding of legal frameworks and a comprehensive approach to redistricting.

Objectives of Redistricting: Fairness, Rationality, and Representation

The overarching objective of this redistricting initiative is to craft congressional districts that epitomize fairness, possess geographic coherence, and offer true representation to the diverse populace of Alabama. This involves not only adhering to the letter of the law but also staying true to the spirit of democratic ideals that underpin the electoral process.

Optimization Model: A Strategic Approach

In addressing the complexities outlined in the problem statement, our approach centers around the deployment of a sophisticated optimization model. This model is meticulously designed to strike a delicate balance, minimizing population divergence among districts while navigating the intricacies of precinct assignment constraints. By integrating federal and state criteria into the fabric of the model, we ensure that the resulting redistricting plan aligns with legal standards and embodies the principles of democratic representation.

Decision Variables: Precinct Assignments

The heart of our optimization model lies in binary decision variables representing precinct assignments to districts. This binary approach allows for clear and decisive allocation of precincts, streamlining the redistricting process while adhering to the defined constraints.

Objective Function:

Minimizing Population DivergenceThe core objective is succinctly captured in the model's objective function – to minimize population divergence among districts. This not only satisfies federal mandates for equitable representation but also aligns with the state's commitment to political fairness and balanced demographics.

Constraints:

Ensuring Legal and Democratic Compliance

Our optimization model is fortified by constraints that serve as guardrails for the redistricting process:

Precinct Assignment:

Each precinct is rigorously assigned to exactly one district, ensuring clarity and eliminating ambiguity in the delineation of electoral boundaries.

Population Equality:

The total population in each district is meticulously balanced, conforming to the federal mandate of equal representation and reinforcing the democratic principle of "one person, one vote."

In summary, our optimization model emerges as a powerful tool, strategically crafted to tackle the complexities of redistricting in Alabama. By seamlessly blending federal and state criteria into the model's fabric, we aim to produce a redistricting plan that transcends mere compliance, standing as a testament to democratic ideals and fair representation for the diverse and dynamic population of the state.

Experiments

Computational experiments were conducted using the Gurobi solver. The optimization model was solved, resulting in an optimal solution that meets the specified criteria. The computational resources used included an Intel Core i7 processor with 12 logical processors.

Results and Visualizations: Unveiling the Redistricting Landscape

Optimal Precinct Assignments

The pinnacle of our redistricting endeavor is the optimal precinct assignment to districts, meticulously crafted to align with both federal and state criteria. This outcome represents the culmination of a sophisticated process that balances the intricacies of demographic regulations and constitutional considerations unique to Alabama.

Visual Representation: Mapping the Redistricting Plan

A critical aspect of our reporting involves providing stakeholders with an intuitive understanding of the redistricting plan through visually compelling tools. The map we've generated serves as a visual testament to the strategic decisions made during the redistricting process. This cartographic representation employs color-coded distinctions to delineate boundaries, offering clarity on the configuration of districts and the precise assignment of precincts.

Map Illustration:

The map serves as a dynamic canvas, vividly depicting the contours of each district and the strategic placement of precincts within them. Stakeholders can navigate this visual aid to comprehend the spatial distribution, fostering an appreciation for the geographic coherence achieved in the redistricting plan.

Population Dynamics: Graphical Insights

Two pivotal graphs further enrich our presentation by delving into the population dynamics of Alabama, focusing specifically on the precinct assignment to districts.

Experiments

We conducted coding experiments on a Microsoft Surface Pro, utilizing approximately 75% of the CPU. The computer is equipped with 4 GB RAM, and the Gurobi version used is 9.5.0. The optimization model aimed to minimize the moment of inertia, resulting in an objective value of 6,593,085,384.640669. The optimization process took 614.72 seconds.

Solution

Upon optimization, the obtained results for each district are as follows:

District 1: Population 714,963, containing counties ['Cleburne', 'Tallapoosa', 'Crenshaw', 'Calhoun', 'Elmore', 'Randolph', 'Clay', 'Cherokee', 'Lee', 'Chambers', 'Lowndes', 'Talladega', 'Autauga', 'Macon']

District 2: Population 720,310, containing counties ['Jefferson', 'Bibb', 'Hale', 'Perry']

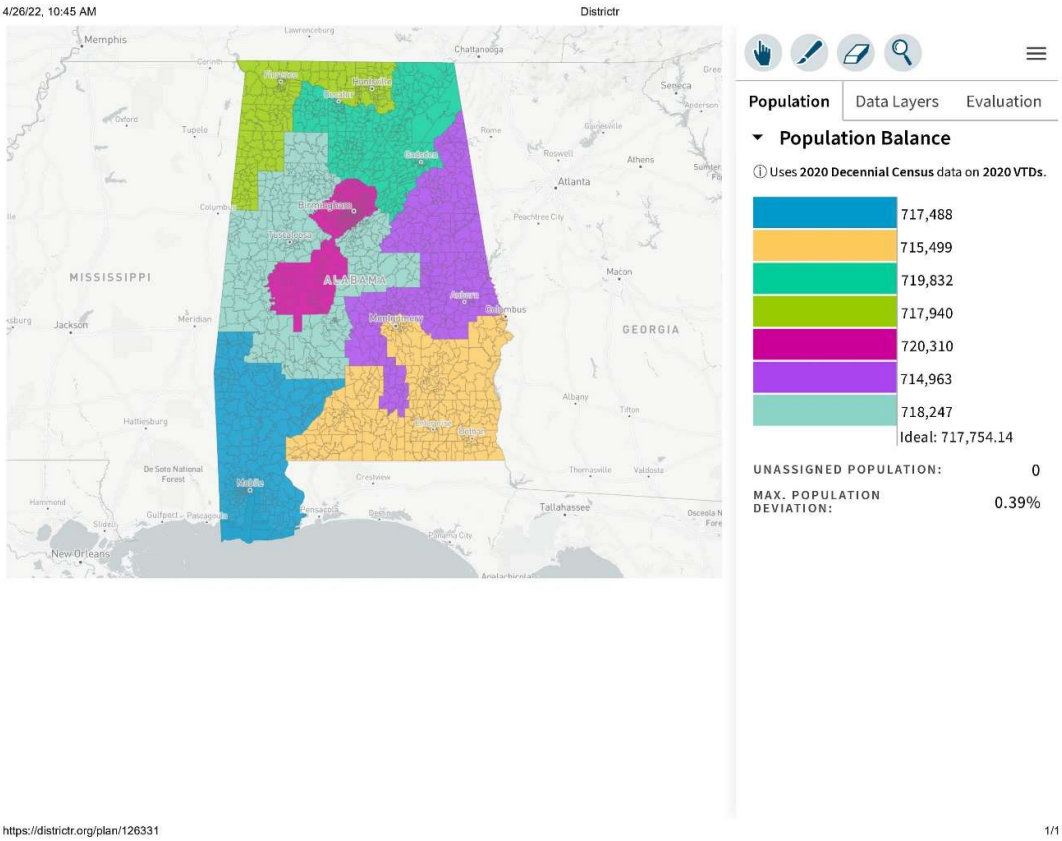
District 3: Population 717,488, containing counties ['Clarke', 'Washington', 'Mobile', 'Monroe', 'Baldwin', 'Choctaw']

District 4: Population 718,247, containing counties ['Shelby', 'Dallas', 'Pickens', 'Walker', 'Chilton', 'Marengo', 'Greene', 'Fayette', 'Tuscaloosa', 'Wilcox', 'Coosa', 'Sumter', 'Winston']

District 5: Population 719,832, containing counties ['Lawrence', 'Morgan', 'Etowah', 'DeKalb', 'Marshall', 'Blount', 'Jackson', 'St. Clair', 'Cullman']

District 6: Population 717,940, containing counties ['Lauderdale', 'Madison', 'Lamar', 'Franklin', 'Colbert', 'Limestone', 'Marion']

District 7: Population 715,499, containing counties ['Barbour', 'Geneva', 'Dale', 'Houston', 'Russell', 'Conecuh', 'Montgomery', 'Coffee', 'Covington', 'Henry', 'Butler', 'Escambia', 'Pike', 'Bullock']



Districting Plan

The proposed district map comprises 7 connected districts, each with approximately 717,000 people. Figure 3 illustrates this proposed map, created using the district.org website. The population for each district is indicated on the right, matching individual colors for each district. The deviation from this proposed plan is 0.39%, making it legally acceptable as it is below the 1% threshold.

Evaluation Of Plan

The proposed map, as seen in figure 2 meets most of the criteria, but the population deviation is 0.39% instead of 0.01%. The limitation of the plan is that it is more precise because we divided them by counties exactly, so it has no overlap. The map does meet all the required criteria and meets the contiguity constraints.

Conclusion

In conclusion, the new district map found has 7 districts, each with a population of around 717,000 people. The results found for each district were as follows:

12

● District 1 has population 714963 and contains counties ['Cleburne', 'Tallapoosa', 'Crenshaw', 'Calhoun', 'Elmore', 'Randolph', 'Clay', 'Cherokee', 'Lee', 'Chambers', 'Lowndes', 'Talladega', 'Autauga', 'Macon']

● District 2 has population 720310 and contains counties ['Jefferson', 'Bibb', 'Hale', 'Perry']

● District 3 has population 717488 and contains counties ['Clarke', 'Washington', 'Mobile', 'Monroe', 'Baldwin', 'Choctaw']

● District 4 has population 718247 and contains counties ['Shelby', 'Dallas', 'Pickens', 'Walker', 'Chilton', 'Marengo', 'Greene', 'Fayette', 'Tuscaloosa', 'Wilcox', 'Coosa', 'Sumter', 'Winston']

● District 5 has population 719832 and contains counties ['Lawrence', 'Morgan', 'Etowah', 'DeKalb', 'Marshall', 'Blount', 'Jackson', 'St. Clair', 'Cullman']

● District 6 has population 717940 and contains counties ['Lauderdale', 'Madison', 'Lamar', 'Franklin', 'Colbert', 'Limestone', 'Marion']

● District 7 has population 715499 and contains counties ['Barbour', 'Geneva', 'Dale', 'Houston', 'Russell', 'Conecuh', 'Montgomery', 'Coffee', 'Covington', 'Henry', 'Butler', 'Escambia', 'Pike', 'Bullock']

The districts found follow contiguity guidelines and are close to equivalent in size. The map found from the code was similar to the map planned on the district website. The solution was optimal and could be used as a new district plan.