Texas Tech University

IE-3311-001

Deterministic Operations Research

Final Project Report

Dr. Hamidreza Validi

Equitable Redistricting: A Comprehensive Analysis and Plan for Arkansas

Team Members:

María Paula Cedeño Vargas

Francisco Herrero Soto

December 12, 2023

Executive Summary

This report details the methodology and outcomes of our team's comprehensive approach to devising a redistricting plan for the State of Arkansas in compliance with federal and state guidelines. The primary objective was to create one or more congressional redistricting plans that ensure population balance while considering traditional redistricting principles, legal requirements, and the recently released 2020 Census data.

In Arkansas, federal criteria prioritize equal population distribution within districts, requiring a 1% deviation limit between district populations. Despite the absence of explicit state-level requirements beyond population balance, our plan integrates principles of compactness and contiguity, aiming to create well-structured and coherent districts.

An optimization model focused on minimizing cut edges between counties aimed to establish compact districts, successfully achieving a low number of 33 cut edges. Technical experiments executed on an MSI GS43vr 7RE Phantom Pro laptop, equipped with a 7th generation Intel HM175 CPU, Nvidia GeForce GTX 1060 GPU, 16 GB DDR4-2400 RAM, and an M.2 NVMe PCLe Gen3 SSD, took approximately 390 seconds to find the optimal solution.

The resulting plan presents four districts with balanced populations: District 1 (751,754 individuals), District 2 (754,547), District 3 (750,788), and District 4 (754,435), meeting the prescribed boundaries and population limits. Our visualized map, generated using Python code with shapefile data, effectively represents the proposed redistricting plan, providing a clear visual illustration for transparency and replicability.

In conclusion, our redistricting approach successfully adheres to federal and state guidelines, ensuring equal population distribution, compactness, and contiguity.

Introduction

This report outlines the comprehensive approach taken by our team in creating a redistricting plan for the State of Arkansas. As per the guidelines provided, our objective was to develop one or more congressional redistricting plans that adhere to both federal and state criteria, considering traditional redistricting principles and legal requirements. These principles include having district populations as equal as practicable, as well as contiguous and compact districts. The project commenced with the formation of teams, selection of the State of Arkansas, and submission of a detailed project proposal. This document represents the culmination of our efforts, which will be submitted by December 12th. Our submission includes the following key deliverables: the final report pdf, python+gurobi codes, and a zip file containing the data sets utilized by said code.

Redistricting Criteria in Arkansas

In Arkansas, the redistricting criteria at both federal and state levels guide the formation of congressional districts. At the federal level, the primary requirement involves ensuring that the populations in congressional districts are as equal as practically possible. Any significant deviation from the average population in a district must be justified, and districts should maintain less than a 1 percent spread between the smallest and largest district populations.

However, at the state level, Arkansas does not impose specific requirements or prohibitions for congressional redistricting. There are no stipulations related to factors such as compactness, contiguity, or favoring or disfavoring particular political parties or candidates. Essentially, the reorganization of districts can occur in any manner as long as it meets the federal requirement for equal population distribution among districts. However, compactness and contiguity are still at the very least encouraged, so we will still consider them while coding.

Background Information on Arkansas

As per the 2020 census data, Arkansas comprises 4 congressional districts, 75 counties, and 823 census tracts. The population of Arkansas stands at 3,011,524 individuals, distributed among the 75 counties within the 4 districts. This information establishes an average or ideal population per district at approximately 752,881. Maintaining a 1% deviation between the largest and smallest districts would result in an acceptable population range between 749,116 at the lowest and 756,645 at the highest for each district.

Problem Statement

The context of this project involves the redrawing of congressional districts in Arkansas, considering the recently released data from the 2020 Census. As hired redistricting consultants, our task is to develop congressional redistricting plans that satisfy legal criteria, encompassing population balance, contiguity, and compactness, among other principles.

OR Model

In words:

The objective function for this model is to ensure the most compact districts possible by minimizing the cut edges between districts. In other words, the districts should be set up in a way that there are minimum edges between the neighboring counties. This ensures compactness and maximizes the chances of districts being contiguous without setting up a constraint specifically for that purpose. The function contains the decision variables x and y, where x is a binary variable that equals 1 when county i is assigned to district j, and y is a binary variable that equals 1 when the edge between county u and county v is cut. The objective function ensures compactness by minimizing the value of y.

As for constraints, each county can only be assigned to one district, the proposed districts must not have a population deviation of 1% or more, which is done by setting constraints that the smallest district cannot have a population smaller than 749,116 and the largest district cannot have a population larger than 756,645, and the edge between counties u and v must be cut if the county u is assigned to district j but the neighboring county v is not.

<u>In math:</u>

Objective function:

Minimize $\sum y$

s.t $\quad \sum_{j=1}^{4} x_i = 1$

$$Total\ Population\ (i)\ *\ x(i,j)\ >=\ 749,116$$

$$Total\ Population\ (i)\ *\ x(i,j)\ <=\ 756,645$$

$$x(u,j)\ -\ x(v,j)\ <=\ y(u,v)$$

$$x, y\ >=\ 0$$

Experiments

During the development of our project, the code was run in an MSI GS43vr 7RE Phantom Pro laptop. Relevant specs include a 7th generation Intel HM175 CPU, an Nvidia GeForce GTX 1060 GPU, 16 GB of DDR4-2400 RAM, and an M.2 NVMe PCLe Gen3 SSD. The objective value of our code was 33 cut edges, and it took the device about 390 seconds to find the optimal solution.

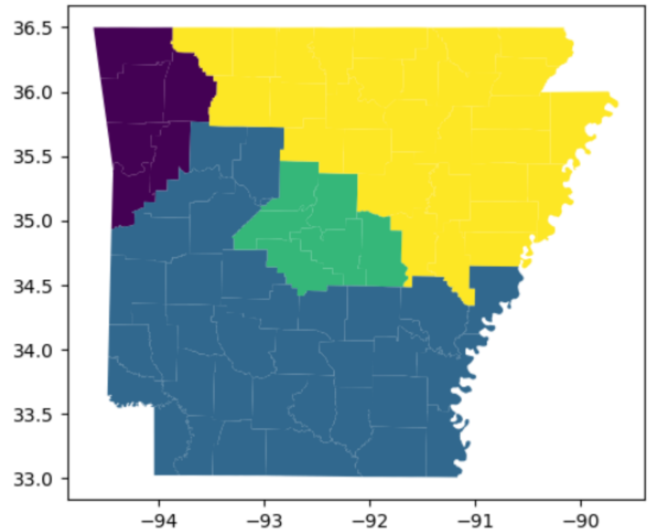
Data Sources

The shapefile data for the mapping section of the code was obtained from Eugene Lykhovyd's index of files for the 2020 census. The JSON file for the Arkansas counties were downloaded from the 'IEM40132020RedistrictingProject' repository in Github by user logandavis2518.

Plan and map

In our proposed plan, District 1 has these counties: Franklin, Crawford, Benton, Madison, Sebastian, and Washington and a population of 751754. District 2 has these counties: Little River, Ashley, Desha, Montgomery, Howard, Nevada, Grant, Dallas, Cleveland, Lafayette, Chicot, Pope, Bradley, Drew, Pike, Union, Hempstead, Polk, Clark, Logan, Miller, Arkansas, Johnson, Garland, Sevier, Jefferson, Lincoln, Scott, Hot Spring, Columbia, Ouachita, Yell, Calhoun, and Phillips and a population of 754547. District 3 has these counties: Faulkner, Conway, Pulaski, Saline, Lonoke, and Perry and a population of 750788. Finally, District 4 has these counties: Jackson, Clay, Baxter, Boone, St. Francis, Sharp, Greene, Woodruff, White, Lee, Crittenden, Marion, Prairie, Lawrence, Poinsett, Stone, Independence, Fulton, Carroll, Van

Buren, Searcy, Randolph, Izard, Craighead, Cleburne, Monroe, Mississippi, Newton, and Cross and a population of 754435.



The image above shows a visualized map of our final proposed redistricting plan, drawn by our Python code using shapefile data downloaded from Eugene Lykhovyd's index of files on US counties.

Evaluation of plan

Upon evaluating our proposed plan, we can see that all the requirements at the federal and state level are fulfilled. Firstly, we can see that none of the populations in the four districts exceeds the lower and upper bounds, so the 1% deviation rule is respected. Additionally, although there are no strict requirements at the state level, since compactness and contiguity are still encouraged, our proposed plan was built with these principles in mind, which as we can see, are also upheld. There are no other criteria or requirements for the state of Arkansas that must be considered. That said, this model may have its limitations. Since it was built with an objective function focused on minimizing the cut edges in order to ensure compactness, a model may exist that has even less population deviation between districts, which would be more ideal. However, there is no guaranteeing that such a model would have compact districts, or even full contiguity.

Conclusions

Our team's redistricting plan for Arkansas adheres to both federal and state guidelines. At the federal level, our plan ensures equal population distribution within districts, maintaining a range within the stipulated 1% deviation limit. While Arkansas does not impose specific requirements beyond population balance, our plan integrates principles of compactness and contiguity, enhancing the overall quality of the proposed districts. The developed optimization model aimed to create compact districts by minimizing cut edges between counties. Our model successfully achieved a low number of 33 cut edges, validating its effectiveness in promoting compactness and contiguity. The proposed districts align with the established criteria, presenting well-structured and coherent boundaries.

The computational experiments were conducted on an MSI GS43vr 7RE Phantom Pro laptop, demonstrating feasible performance metrics. With a 7th generation Intel HM175 CPU, an Nvidia GeForce GTX 1060 GPU, 16 GB of DDR4-2400 RAM, and an M.2 NVMe PCLe Gen3 SSD, the optimization process took approximately 390 seconds to find the optimal solution.

The delineated districts reflect balanced populations, with District 1 totaling 751,754 individuals, District 2 with 754,547, District 3 with 750,788, and District 4 with 754,435 residents. Each district composition conforms to the prescribed boundaries, meeting the specified population limits. Our proposed redistricting plan meets the established criteria, encompassing equal population distribution, compactness, and contiguity. While acknowledging the fulfillment of legal requirements, it's important to note the potential for further optimization. Alternative models might achieve even lower population deviation between districts, yet this could compromise the compactness and contiguity principles laid out in our model. The visualized map generated by our Python code, utilizing shapefile data from Eugene Lykhovyd's index of US county files, effectively represents the final proposed redistricting plan. The utilization of such data aids in the transparency and replicability of the proposed plan's visualization.

Github submission

This report, our code and all relevant data utilized during the development of this project has been uploaded to the following public GitHub repository: https://github.com/FranHerrero224/TTU-Fall-2023-OR-Redistricting-Project.git

Acknowledgements

Special thanks and reference to Austin Buchanan, who's GitHub repository 'Districting-Examples-2020' served as a major point of guidance while developing this project.

References

Buchanan, A. (2023). Districting-Examples-2020. AustinLBuchanan. https://github.com/AustinLBuchanan/Districting-Examples-2020.git

Davis, L. (2022). IEM40132020RedistrictingProject. logandavis2518. https://github.com/logandavis2518/IEM40132020RedistrictingProject.git

Eugene Lykhovyd's 2020 data. (2021). OR Redistricting Resources - Austin Buchanan. https://austinlbuchanan.github.io/OR-redistricting-resources/

Redistricting - Ballotpedia. (n.d.). Ballotpedia. https://ballotpedia.org/Redistricting

Redistricting criteria. (2021). National Conference of State Legislatures. https://www.ncsl.org/redistricting-and-census/redistricting-criteria

Redistricting in Arkansas after the 2020 census - Ballotpedia. (n.d.). Ballotpedia. https://ballotpedia.org/Redistricting_in_Arkansas_after_the_2020_census