Algorithmic Redistricting the State of Tennessee

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I. Introduction:

This group was challenged with a project involving redistricting the State of Tennessee. The goal is to better represent the state's population by evenly distributing constituents among their representatives. The team has accomplished this redistricting through linear programming, integer programming, and network modeling in Python. The key focuses for the optimization process are population balance, contiguity, and distance minimization. Using reliable data sources, we identified several key constraints and defined the objective function to focus our efforts toward an optimal solution.

II. Data Sources:

The datasets used for this project are derived from multiple sources. These data sources provided geographic information, ranging from county-level population data, geospatial data for measuring distances, and adjacency information to identify which counties share borders. The specific source used by the group is the United States Census Bureau. The group has determined that this is a reliable and consistent data source for the project, allowing the group to program the redistricting model without reservations regarding data accuracy or bias. The exact details of the data source are listed in the References section of the Appendix for further review.

III. Specifications

The project consists of several key constraints to achieve an optimal redistricting solution. The first constraint ensures that each county is assigned to exactly one district by requiring that the sum of its district assignments equals one. The second constraint enforces the principle of one-person-one-vote by requiring that the population of each district remains between 95% and 105% of the target population, which is the state's total population divided by the number of districts. This ensures equal representation across districts. The third constraint guarantees geographic contiguity by ensuring that a county can only be part of a district if at least one of its neighboring counties is also assigned to the same district. This prevents the formation of disjointed districts and maintains logical geographical boundaries. Finally, the fourth constraint ensures that the model properly tracks which pairs of counties belong to the same district, allowing the objective function to minimize intra-district distances accurately. The objective function itself aims to create geographically compact districts by minimizing the total distance between counties within each district, using geographic coordinates to calculate distances. Full problem formulation can be found in Appendix A. By integrating these constraints with the objective function, the model produces a well-balanced districting plan that prioritizes population equality, geographic compactness, and district contiguity.

IV. Solution

Given the complexity of the problem, we split Tennessee into smaller groupings of contiguous counties to have the adjacency constraint apply. By iterating over smaller chunks and opening up the population minimum and maximum constraint, we were able to create a model that assigns most counties to districts. While the populations of the counties are fairly similar, there are a few outliers, District 6 has a population of 546,268 while District 9 has a population of 929,744.

Given some counties were manually assigned, we were unable to fully optimize and solve the application of population and adjacency constraints. One drawback of the method is that whenever a section of the state is being run, the county options are limited due to the boundaries needed. Unfortunately, this constraint limits the best possible district makeup to what is already drawn.

V. Maps and Discussion

Other possible plans for Tennessee can be found at Tennessee Lookout (Appendix A). While the Fair Map Proposal (using 2019 American Community Service data) does split counties, the counties split are those that do have significantly different populations so that districts are around the same size. Given that the population of a district determines the "one person, one vote" principle, we recommend splitting counties as needed to help ensure equal representation and political equity. Tennessee legally allows gerrymandering so if counties can be split to allow for more equal voting power between districts, split counties should be included in the creation of the districts. These plans are as close to fair and equitable as possible given the population constraints.

VI. Conclusion

This project's objective was to redistrict the State of Tennessee to provide a more fair representation of the population. Using data directly from the U.S. Census Bureau and developing constraints to provide balance and county adjacency requirements, the model effectively optimized the redistricting solution. The division of Tennessee into smaller regions improved the outcome of the model's performance and properly distributed the districts within their respective bounds. The model demonstrates how proper data-driven solutions can improve fair redistricting efforts. Future improvements could balance the districts further, adhering to political guidelines better.

Appendix

Appendix A

Decision Variables:

- $x_{i,j} \in \{0,1\}$
- $y_{i,j,d} \in \{0,1\}$

Objective Function:

$$\min \sum_{(i,j)\in P} \sum_{d\in D} y_{i,j,d} \cdot d_{i,j}$$

Constraints:

$$\sum_{j\in D} x_{i,j} = 1 \quad \forall i \in \text{county\_list}$$

$$\sum_{i\in \text{county\_list}} pop_i \cdot x_{i,j} \geq \text{pop\_min} \quad \forall j \in D$$

$$\sum_{i\in \text{county\_list}} pop_i \cdot x_{i,j} \leq \text{pop\_max} \quad \forall j \in D$$

$$x_{i,j} \leq \sum_{neighbor\in \text{neighbors}(i)} x_{neighbor,j} \quad \forall i \in \text{county\_list}, j \in D$$

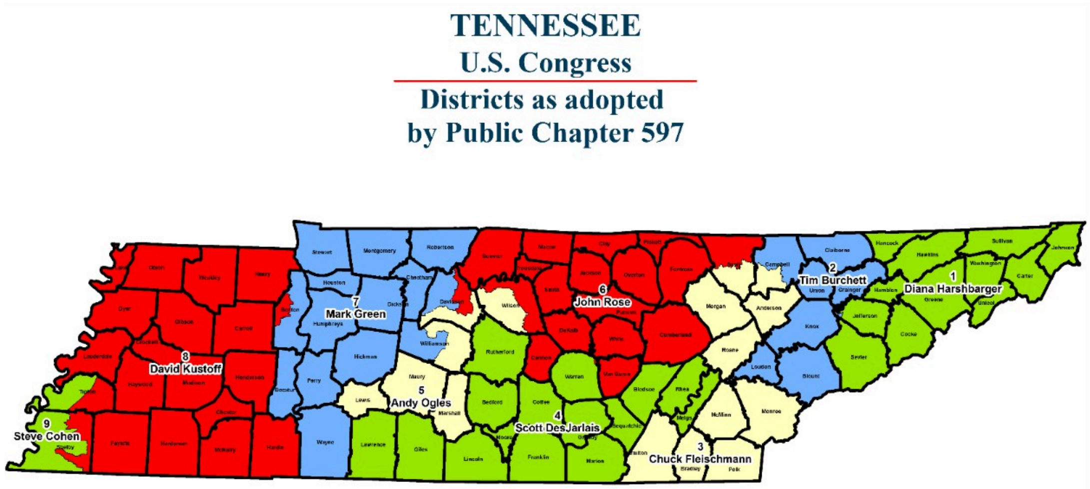
$$y_{i,j,d} \leq x_{i,d} \quad \forall (i,j) \in P, d \in D$$

$$y_{i,j,d} \leq x_{j,d} \quad \forall (i,j) \in P, d \in D$$

$$y_{i,j,d} \geq x_{i,d} + x_{j,d} - 1 \quad \forall (i,j) \in P, d \in D$$

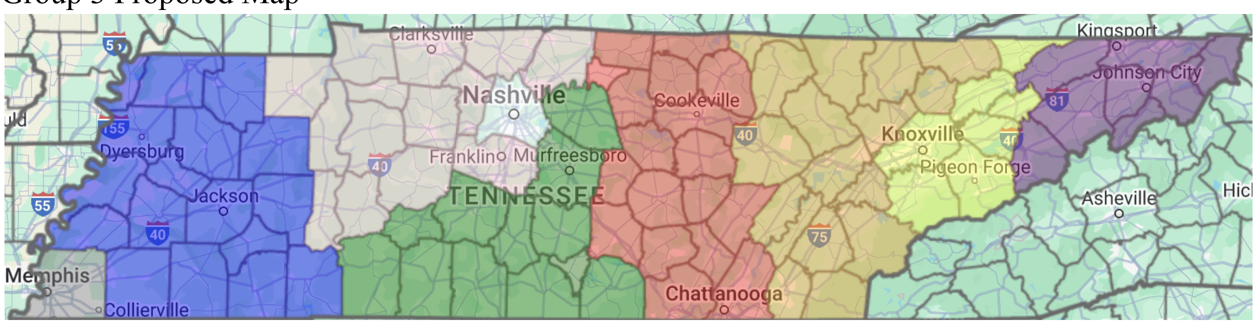
Maps

Current Tennessee Congressional Districts



“U.S. Congress Districts.” *U.S. Congress Districts*, comptroller.tn.gov/maps/u-s--congress-districts.html. Accessed 15 Feb. 2025.

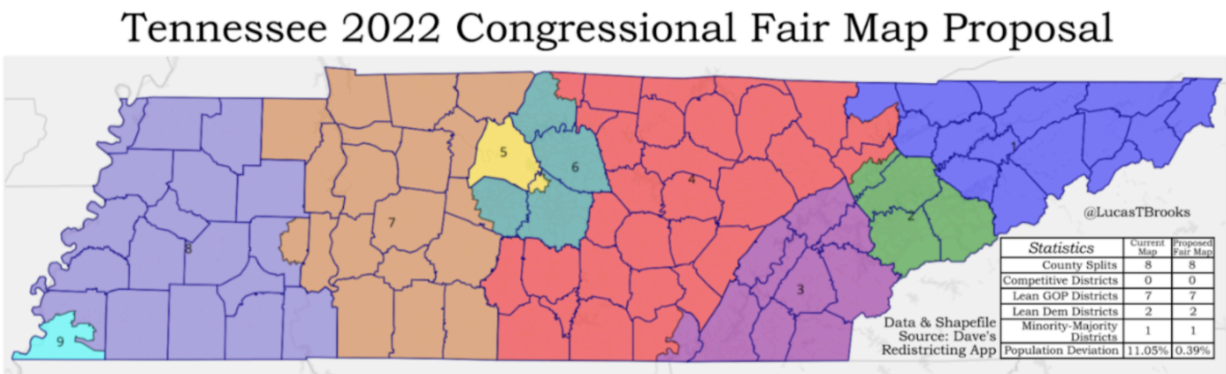
Group 3 Proposed Map



District	Population	Color
1	965,985	Peach
2	568,407	Blue
3	862,625	Green
4	784,557	Red
5	675,368	Orange
6	546,268	Purple
7	862,002	Yellow
8	715,884	White

9	929,744	Grey

Tennessee Lookout Fair Map Proposal



References

Brooks, Lucas. “Redistricting in Tennessee: An Explanation of How the System Works • Tennessee Lookout.” *Tennessee Lookout*, 24 June 2021, tennesseelookout.com/2021/06/24/redistricting-in-tennessee-an-explanation-of-how-the-system-works/.

United States Census Bureau. n.d. “Explore Census Data.” United States Census Bureau. https://data.census.gov/.