Integer Programming:

Balancing Indiana's Congressional Districts at the County-Level

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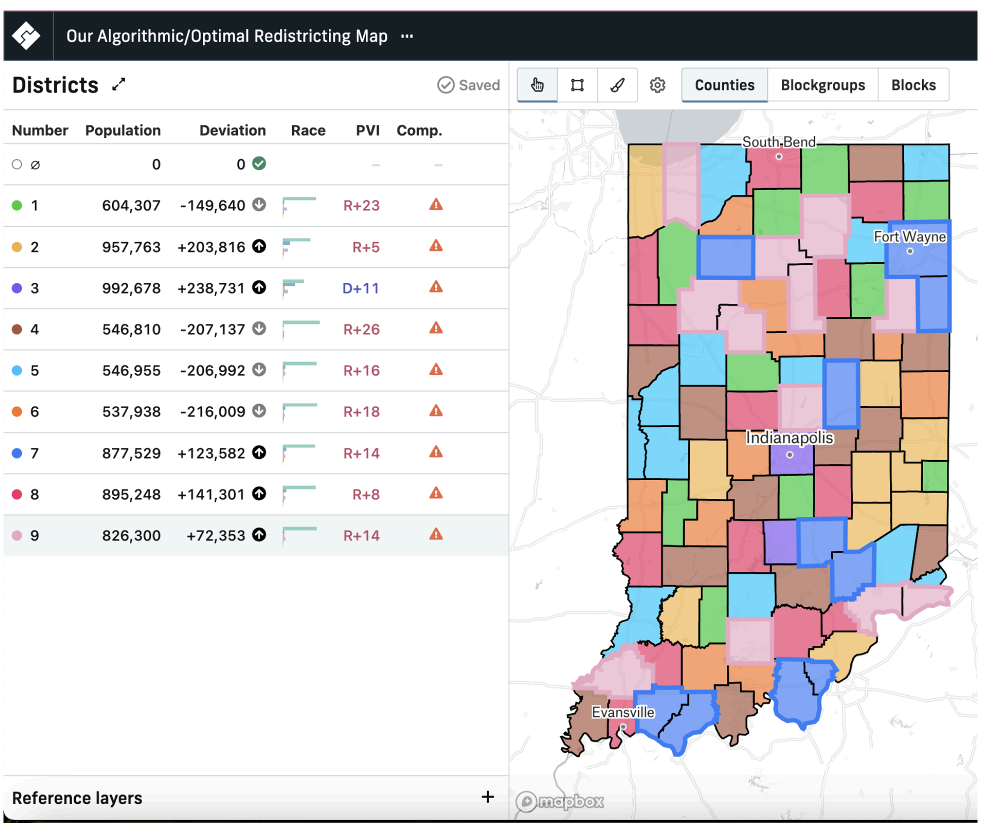
Executive Summary:

Integer linear programming was applied to determine an optimal solution for assigning Indiana counties to one of nine congressional districts while meeting a set of five constraints. The objective included minimizing the number of assignments of counties that were assigned to one of nine congressional districts (i.e., Indiana counties can be assigned to one congressional district only). The constraints that were explored included: 1) the nine congressional districts should be within +/- 30% of the average population (total state population divided by 9 districts; *M*= 759,226 people); 2) Each county can only be assigned to one district; 3) Counties with populations greater than 760,000 are assigned to their own district; 4) No district can be comprised of more than 95% white-only identifying people; and 5) districts should be comprised of adjacent counties (referred to as compactness). The resulting congressional district assignments of Indiana counties are shown below (DistrictBuilder, 2024.)



The nine congressional districts had populations ranging from a minimum of 544,918 people to a maximum of 985,036 people. Out of the five constraints that were explored, constraint 1 and constraint 2 were satisfied, while constraint 3 and constraint 4 resulted in infeasible solutions and constraint 5 could not be implemented due to a lack of computational resources. Future directions must find computationally accessible solutions that implement constraint 5 before this solution (refer to the choropleth map) can be recommended to Indiana's state legislature.

Method:

Data were pulled from an Indiana state government database (Staff, 2021) that relied on data collected by the US 2020 Population Census. The dataset contained data about Indiana counties, latitude and longitude information, racial and ethnic composition, and total population per county. All analyses were conducted in Spyder/Python using the *pulp, pandas, pyproj, geopandas, and matplotlib* packages.

The first constraint in this integer programming problem consisted of balancing the number of people comprising the nine districts such that each district had roughly equal populations. It is impractical to expect equal populations across districts, thus a margin of difference was explored. When this was relaxed to any value under a 30% difference threshold, the program produced an infeasible output (thresholds as small as a 2.5% difference were explored). An optimal solution was produced when this was relaxed to +/- 30%. The second constraint was easily met (each county could be assigned to one district only).

Infeasible solutions were produced for all constraint relaxation attempts for constraint 3 and constraint 4. Constraint 3 and Constraint 4 were dropped. The US Census suggested that at the national level, each congressional district was accountable to, on average, ~760,000 people.

Thus, the threshold was set initially to this value and it produced an infeasible solution. This was relaxed to as low as 300,000 as about four Indiana counties were above this count, but this also produced infeasible solutions. Next, constraint 4 explored racial balancing (white-only compared to people of color; people of color are interchangeable with non-white) across districts. This was explored such that none of the nine districts could be more than 85% white, and this was relaxed to be as high as 99%. Nonetheless, this was infeasible due to the racial composition of Indiana, which is majority white-only.

The final constraint explored assigning adjacent counties to the same districts. To do so, the distance between two counties was defined and then iterated over all possible pairs of counties. Then, constraint 5 was added to the programming file but was removed from the solution because of over 12 hours of processing time (and still running). This suggested that there was a lack of computational resources.

Maps and Discussion:

Our study utilized integer linear programming to develop an optimal redistricting plan for Indiana, considering factors such as population balance, racial composition, and compactness. However, computational constraints limited the feasibility of certain constraints, such as racial balancing and compactness. The actual redistricting process likely involved political negotiations and legal requirements, resulting in a map reflecting policymakers' decisions. Comparing our algorithmic/optimal redistricting with plans from tools like Districtr reveals potential differences in district boundaries, population distribution, and adherence to fairness and equity principles. The recommended redistricting plan for Indiana should prioritize fairness, equity, and the principle of one-person, one-vote, by ensuring equal representation for all citizens, avoiding gerrymandering, and balancing various considerations such as population balance and community coherence.

References

1. Staff, A.C. (2021) *Indiana's population rose 4.7% since 2010*, *Census.gov*. Available at: https://www.census.gov/library/stories/state-by-state/indiana-population-change-between-census-decade.html (Accessed: 05 May 2024).
2. *Our Algorithmic/Optimal Redistricting Map* (2024) *Districtbuilder*. Available at: https://app.districtbuilder.org/projects/25a02bf8-4d50-4f05-a8f1-eeb5ce541949 (Accessed: 05 May 2024).