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Operations Research

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Final Deliverable: Wisconsin Gerrymandering Analysis

Wisconsin is made up of 72 counties and 8 different electoral districts. Currently, Wisconsin’s electoral districts are primarily split up by counties, however, some of the counties are in multiple districts. This helps to balance the population as the districts do not have an even number of people in each of them. However, for simplicity, our attempts only group electoral districts by entire counties. This can still be difficult as some of the counties have populations that are larger than 1/8th of the total state population. Milwaukee county, specifically, has over 900,000 people. This is approximately 450,000 more than 1/8th of the total population, so having Milwaukee be its own district is a necessity. Thus, we hard-coded it as district 1 for each of the attempts.

The seeded counties for each attempt were chosen methodically. For our first attempt, we desired to space them out around the perimeter of the state with having more seeds concentrated in areas of higher population density (the population of Wisconsin tends to increase as you move south and east). This would allow the districts to grow inwards and not have a super weird district path that wrapped around other districts. For our second attempt, we similarly tried to space our seeds out, but we included counties that were not all on the perimeter. We wanted to see if this would produce more “square-like” districts. For our third attempt, we chose seeds fairly randomly, trying not to pick counties that were too geographically close to each other.

To measure the fitness for each of the redistricting options, we decided to use the length-width test. The measurement for this test involved comparing the length and width of the smallest possible rectangle that could bound the entire district. We then calculated the difference between that ratio and 1 for each of the districts. Finally, we took an average of all of those differences. We refer to this value as the *measure of fitness* and the closer this value is to 0, the fairer the result. These calculations can be seen in the Excel addendum in the sheets titled “L-W #n”.

To measure the minimax of district population difference, this is where our OpenSolver model came into play. These models can be seen in the Excel addendum in the sheets titled “Attempt #n”. This metric was the maximum difference between the total population of any one district and the total population of another district. The lower this value, the fairer the population distribution was for the districts.

To measure the Maximum Republican Regret we first created a simple table of the number of the Republican electoral vote results by type and year of election and compared it by each of our redistricting seeding attempts. After creating this table, another was created with the same layout. This table measured regret. We filled it in by comparing the current cell (number of Republican votes) to the max in that column (or the max of the different seeding attempt) to get the Republican regret if making that decision. Finally, we analyzed these results by performing minimax methodologies (or minimizing the most regret we could have for a decision). To do this, we first calculated the max regret by column (or seeding attempt), and then finalized the answer by selecting the smallest (min) maximum regret value.

**Redistricting Attempt #1 (option #1)**

Seeded counties: Milwaukee, Sheboygan, Florence, Bayfield, Trempealeau, Grant, Rock, and Measure of fitness: 0.478

Minimax of district population: 284,497

Max Republican regret: 1

Max Democrat regret: 1

Although this attempt produced the smallest maximum population difference between all the districts, it was the worst when it comes to fairness. Many of the districts in this attempt are oddly shaped and not geographically centered around the seed. Most of the districts, outside of the one with Milwaukee county, are fairly close in their population which is good when it comes to evaluating fairness in regards to population alone.

The Max Republican regret, in this case, is tied for the lowest meaning if the Republican party were to have the opportunity to vote for this selection and valued regret highly, Attempt #1 would be a valued option for them. The Max Democrat regret, in this case, is tied for the lowest meaning if the Democratic party were to have the opportunity to vote for this selection and valued regret highly, Attempt #1 would be a valued option for them.

**Redistricting Attempt #2 (option #2)**

Seeded counties: Milwaukee, Sauk, Jackson, Waupaca, Door, Forest, Dunn, Douglas

Measure of fitness: 0.382

Minimax of district population: 396,065

Max Republican regret: 1

Max Democrat regret: 2

Although this attempt produced the smallest measure of fitness, it has the worst maximum population difference between districts. This means this attempt has many “square-like” districts but these districts have higher differences in their populations.

The Max Republican regret, in this case, is tied for the lowest meaning if the Republican party were to have the opportunity to vote for this selection and valued regret highly, Attempt #2 would be a valued option for them. The Max Democrat regret, in this case, is the highest meaning if the Democratic party were to have the opportunity to vote for this selection and valued regret highly, Attempt #2 would not be a valued option for them.

**Redistricting Attempt #3 (option #3)**

Seeded counties: Milwaukee, Walworth, Green, Crawford, Manitowoc, Marinette, La Crosse, Taylor

Measure of fitness: 0.448

Minimax of district population: 288,906

Max Republican regret: 2

Max Democrat regret: 1

This attempt resulted in middle-of-the-road values for the measure of fitness and the minimax of the district population. In many ways, it could be said that this attempt was a good middle ground and tried to value both a geographically square district as well as a pretty even population distribution between the districts. This attempt was nearly better than the first attempt when it came to the minimax of the district population as well.

The Max Republican regret, in this case, is the highest meaning if the Republican party were to have the opportunity to vote for this selection and valued regret highly, Attempt #3 would not be as good option for them. This does not mean this option is objectively bad, however. The Max Democrat regret, in this case, is tied for the lowest meaning if the Democratic party were to have the opportunity to vote for this selection and valued regret highly, Attempt #3 would be a valued option for them.

**Final Recommendation**

1. Based on the optimistic approach, the Republicans would be tied between choosing option #1 and option #2 as both have an election with a result of 7 districts in their favor. The Democrats would choose option #3 as it has an election with a result of 6 districts in their favor.
2. Based on the conservative approach, the Republicans would not favor any decision over another because their opponents, the Democrats, have the same minimum for all of them. The Democrats would choose option #3, because that’s where the Republicans have the lowest minimum.
3. As stated in the descriptive paragraphs above (under each option), based on the minimax regret approach, the Republicans would choose either option #1 or option #2. The Democrats would favor option #1 or option #3.
4. Although not required, we also calculated the expected value for each option which was essentially the average result. For option #1 the EV(Republicans) is **4.86** and the EV(Democrats) is **3.14**. For option #2, the EV(Republicans) is **5.14** and the EV(Democrats) is **2.86**. For option #3 the EV(Republicans) is **4.79** and the EV(Democrats) is **3.21**.

* Overall, the Republicans should choose option #2 as it equally favorable to option #1 but had a better expected value (which we used as the tie-breaker)
* Overall, the Democrats should choose option #3, as it was favorable in every single approach.

The most fair approach overall would be **option #2**. Although this is the most likely choice for the Republicans, that choice was made very narrowly between option #1 and option #2 for them. It would not be fair to pick the Democrat’s obvious choice, so we avoided picking option #3. This option seems to keep districts geographically central and in a fairly normal shape which is valuable. With this option, the state would expect somewhere between 4 and 7 Republicans, but likely would get 5 Republicans. The inverse of this is true for the Democrats; the state would expect somewhere between 1 and 4 Democrats, but likely would get 3.

*Decision Tree*