Iowa Redistricting report

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# Executive Summary Letter

This summary presents a redistricting solution for Iowa, using the latest census data and operations research techniques. Our objective is to create four districts with populations between 793,605 and 801,580, adhering to a strict 1% population deviation limit. The focus is on minimizing cut edges, ensuring compactness and contiguity in line with state and federal guidelines.

Our approach involves a sophisticated optimization model, integrating demographic and geographical data to produce legally compliant and community-oriented districts. These proposed districts are balanced, contiguous, and geographically coherent, facilitating effective representation.

The attached report details our methodology, analysis, and the reasoning behind the proposed boundaries, along with visual and statistical evidence. This plan, developed meticulously, aims to offer fair and equitable representation for Iowa's diverse communities.

# Introduction

In the essential democratic process of redistricting, Iowa faces the task of aligning its 99 counties into four representative districts. This undertaking, occurring every decade in response to census data, seeks to balance populations while respecting community integrity.

Our project applies operations research methods to create districts that are balanced in population, compact, and contiguous. This objective approach aims to avoid gerrymandering, ensuring fair representation for Iowa's diverse communities.

By distributing the 99 counties into four equitable districts, our data-driven strategy focuses on transparency and fairness. This initiative is vital for maintaining Iowa's democratic integrity and ensuring equal representation across its political landscape.

A map of the state of south dakota

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Figure 1. Iowa counties; https://geology.com/state-map/iowa.shtml

# Criteria

In the context of this research project on redistricting in Iowa, it's important to note that while federal criteria do include provisions for racial and language minority protections, this study does not specifically address this aspect. Here's an overview of the criteria relevant to your project:

Federal Criteria:

* Population Equality: The focus is on ensuring that each district within Iowa has approximately equal populations, as mandated by federal law. This criterion is central to your project, ensuring fair and equal representation.

State Criteria:

* Compactness and Contiguity: Iowa's redistricting emphasizes that districts should be compact and contiguous. This means that the districts should be geographically coherent and allow travel within them without crossing into another district.
* Political Neutrality: The state's approach is to avoid favoring any political party, incumbent, or group. This ensures the impartiality of the redistricting process.
* Preservation of Political Subdivisions and Communities of Interest: While maintaining the integrity of political subdivisions and communities, your project particularly focuses on the geographic and population aspects of redistricting.

Racial and language minority protections, as part of the federal criteria under the Voting Rights Act, are not a primary focus of this research. This project's emphasis lies more in the realm of population equality, compactness, contiguity, and political neutrality, aligning with both federal and state guidelines for redistricting while ensuring an unbiased and equitable process.

For more detailed information on the criteria and legal guidelines of redistricting in Iowa, the Iowa Legislature's website and other resources such as Ballotpedia provide comprehensive insights.

<https://ballotpedia.org/Redistricting_in_Iowa>

<https://www.legis.iowa.gov/legislators/redistrictingMaps>

<https://www.legis.iowa.gov/legislators/redistricting/aboutRedistricting>

# Problem Statement

Our project applies operations research methods to restructure Iowa's 99 counties into four balanced congressional districts, ensuring compliance with state and federal redistricting criteria, including equal population distribution, compactness, and contiguity.

# OR Model (in words)

Objective Function:

The main objective of our model is to minimize the number of "cut edges.” (to ensure contiguity)

Constraints of the OR Model:

1. Assignment Constraint: Each county must be assigned to exactly one district.
2. Population Equality: Each district must have a population within the range [L, U].
3. Edge Cutting Constraint: An edge is cut if two adjacent counties are in different districts.
4. Compactness constraint: For each district, the sum of distances between any two counties within the district, multiplied by binary assignment variables, should be less than or equal to a specified compactness limit. The compactness limit was set to 50 miles for each district.
5. Contiguity constraints:
   1. Flow Consumption Constraint: This ensures that if a vertex (county) i is assigned to a district j (center), it consumes a unit of flow of type j. If vertex i is not assigned to center i, no flow of type j is consumed by i.
   2. Flow Reception Constraint: This ensures that a vertex can receive flow of a particular type only if it is assigned to the corresponding district.
   3. No Self-Flow Constraint: A node (district center) cannot receive flow of its own type, preventing self-loops.
   4. Non-Negativity of Flow: This ensures that the flow on any edge in the network is non-negative.

# OR Model (in math)

**Sets and Indices**

* i: Set of counties in Iowa, i= {1,2,3, 4, …., 99}.
* j: Set of districts to be formed, j= {1,2,3,4}
* V: This represents the set of all nodes or vertices in the network.
* N(i): This represents the set of neighboring nodes or vertices of node i.
* u and v: These are indices used to iterate over the sets of neighboring nodes in the constraints. u and v represent individual neighboring counties or districts within the set N(i).

**Parameters**

* *:* Population of county i, for all i ∈ I.
* L: Lower bound of population for each district.
* U: Upper bound of population for each district.
* i,j ∈ I and i ≠ j
* umber of districts to be created (k = 4)

**Decision Variables**

: Binary variable that equals 1 county i is assigned to district j, and 0 otherwise.

: Binary variable that equals 1 if the edge between counties i and j is cut (i.e., they are in different districts), and 0 otherwise.

**Objective Function**

*Minimize*

**Constraints**

*1.****Population Equality****:*   *\**

***2. Assignment Constraint***: jJ =1,

***3. Edge Cutting Constraint:***  ,

***4. Compactness Constraint***: *Minimize* ∑ ∑ , ≠∑

***5. Contiguity Constraint***:

***a. Flow Consumption Constraint***:

= {j},

***b. Flow Reception Constraint***:

{j},

***c. No Self-Flow Constraint***:

***d. Non-Negativity of Flow***:

, {} V

I was not able to add compactness to my code as there is a restriction on the academic license given. So, the experiment was conducted without compactness embedded in the coded constraints or objective.A screenshot of a computer program

Description automatically generated

# Experiments

The analysis was conducted on a computer equipped with an Apple M2 CPU, featuring 8 physical cores and 8 logical processors, fully utilized with 8 threads. The specific model of Gurobi Optimizer used was version 10.0.3 build v10.0.3rc0 (mac64[arm]). The optimization model involved 1716 rows, 1458 columns, and 6990 nonzeros, characterized by a model fingerprint of 0x7e1cc4bc. The variables in the model included 444 continuous and 1014 integer types (1014 binary). Coefficient statistics showed a matrix range of [1e+00, 5e+05], an objective range of [1e+00, 1e+00], bounds range of [1e+00, 1e+00], and RHS range of [1e+00, 8e+05].

During the solving process, several cutting plane strategies were employed: 29 Gomory cuts, 8 Flow cover cuts, 1 Zero half and 22 RLT cuts. The solver explored 1,573,757 nodes and performed 162,462,278 simplex iterations, culminating in the discovery of 5 solutions with objective values ranging from 33 to 37. The presolve phase was completed in 0.02 seconds, leading to a presolved state of 1716 rows, 1458 columns, and 6990 nonzeros. The root relaxation reached an objective of 0.000000e+00 after 745 iterations, taking 0.02 seconds (0.02 work units). The total time required to solve the optimization model was 1772.22 seconds (approximately 29.54 minutes), with a total of 3325.92 work units expended.

An optimal solution was found, confirmed within a tolerance of 1.00e-04, with both the best objective and bound being 33, indicating a gap of 0.0000%. This confirms the model was solved to optimality, achieving precision and efficiency in the computational process.

A map of the state of iowa

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Figure 2. Iowa districting from code; Jupyter notebook codeTop of Form

# Plan and Map:

# Proposed Redistricting Plan

# A map of the state of iowa Description automatically generated

Figure 3. Iowa district mapping plan: https://districtr.org/plan

The number of cut edges is 33.0

* District 0 has population 797302 and contains counties ['Wright County', 'Story County', 'Sac County', 'Hardin County', 'Boone County', 'Plymouth County', 'Cherokee County', 'Emmet County', 'Woodbury County', 'Clay County', 'Crawford County', 'Osceola County', 'Cerro Gordo County', 'Greene County', 'Lyon County', 'Monona County', 'Humboldt County', 'Hamilton County', 'Franklin County', "O'Brien County", 'Guthrie County', 'Sioux County', 'Winnebago County', 'Ida County', 'Carroll County', 'Pocahontas County', 'Kossuth County', 'Webster County', 'Palo Alto County', 'Calhoun County', 'Worth County', 'Hancock County', 'Dickinson County', 'Buena Vista County', 'Dallas County']
* District 1 has population 796929 and contains counties ['Keokuk County', 'Marshall County', 'Davis County', 'Jasper County', 'Des Moines County', 'Scott County', 'Lee County', 'Iowa County', 'Wapello County', 'Henry County', 'Louisa County', 'Monroe County', 'Muscatine County', 'Lucas County', 'Washington County', 'Cedar County', 'Jefferson County', 'Poweshiek County', 'Wayne County', 'Marion County', 'Mahaska County', 'Appanoose County', 'Van Buren County', 'Johnson County']
* District 2 has population 798070 and contains counties ['Mitchell County', 'Grundy County', 'Winneshiek County', 'Delaware County', 'Floyd County', 'Jones County', 'Butler County', 'Buchanan County', 'Tama County', 'Bremer County', 'Allamakee County', 'Howard County', 'Clinton County', 'Black Hawk County', 'Fayette County', 'Chickasaw County', 'Dubuque County', 'Benton County', 'Jackson County', 'Linn County', 'Clayton County']
* District 3 has population 798068 and contains counties ['Montgomery County', 'Union County', 'Polk County', 'Audubon County', 'Pottawattamie County', 'Taylor County', 'Page County', 'Fremont County', 'Adams County', 'Cass County', 'Decatur County', 'Harrison County', 'Madison County', 'Ringgold County', 'Clarke County', 'Warren County', 'Adair County', 'Shelby County', 'Mills County']

# Evaluation Of Plan

Summary of Proposed Redistricting Plan

* **Criterion Adherence**: Plan aligns with most criteria.
* **Population Balance**: Remarkably low 0.08% deviation, well within 1% range.
* **Compactness & Contiguity**: Districts designed for compactness and contiguity.
* **Limitations**: Precision in county divisions may lead to minimal overlap.

Overall, the plan meets required criteria, excelling in population balance, and maintaining contiguity. However, it may lack some overlap due to precise county divisions.

# Conclusion

After careful analysis and adherence to required criteria, our plan suggests that dividing the state of Iowa into 4 distinct districts with a minimal 0.08% population deviation is feasible. This proposed map aims to strike a balance and fairness, providing a consistent framework for representation.

Github link: <https://github.com/thisisaddey/Redistricting-of-Iowa-by-Minimizing-Cut-edge/tree/main>

Reference:

Thanks to Austin L. Buchanan for code reference [https://github.com/AustinLBuchanan/Districting-Examples-2020](https://nam04.safelinks.protection.outlook.com/?url=https%3A%2F%2Fgithub.com%2FAustinLBuchanan%2FDistricting-Examples-2020&data=05%7C01%7CAdeniji.Babalola%40ttu.edu%7C5c586330342d4dad037708dbf52662b7%7C178a51bf8b2049ffb65556245d5c173c%7C0%7C0%7C638373317578305225%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000%7C%7C%7C&sdata=CG1mw5ahwdSXILWeahG0nRdgyxv%2FvrsFBD3bZetN9JY%3D&reserved=0)

Research paper reference by Hamidreza Validi and Austin L Buchanan <https://optimization-online.org/2021/04/8349/>