

FINAL REPORT: The Terrific Trio

STATE: IOWA

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EXECUTIVE SUMMARY LETTER:

The Terrific Trio has been presented with the task of redrawing the congressional districts in the state of Iowa. The 2018 census data will show the change in demographics and it is our job to make new plans that satisfy traditional redistricting principles, as well as, state and federal laws. This plan must be transparent, well-documented, and presented in a report. With this situation given, our team came up with the following solution with an OR model. We will divide Iowa into 4 districts where each has a population between 758,120 and 764,233. These districts will be made of compact, continuous counties and found using Gurobi optimizer version 9.1.1. Our goal is to minimize the moment of inertia equation using constraints like population bounds, limiting each county to only one district, and making sure each district is continuous. After using our program we found the right set of counties to define each district and displayed our findings on a map of the state.

INTRODUCTION:

Redistricting is the process of drawing new electoral district boundaries so that each voting district has roughly the same population. States must redraw their boundary lines every 10 years once the new census data is released regarding its population. Each state has its own laws and principles about how to redistrict and it can be a tricky process. Redistricting is extremely important in modern society due to its effect on politics and diversity. The manipulation of district lines, often referred to as gerrymandering, has the power to distort representation which is why it is in our hands to form an honest, and lawful plan. With this information, our goal is to redistrict the state of Iowa with the new data and have it conform to the laws and criteria given to us using OR methods.

CRITERIA:

Legislative & Congressional Criteria:

- Required: Compact, Contiguous, Preserve Political Subdivisions
- Prohibited: Intentionally Favor a Party, Incumbent, Person or Group; Use Partisan Data

These criteria intend fairness and consistency, while ensuring that the districts will be easy to identify and understand. Iowa adopted many of the traditional districting principles such as compactness, contiguity, and preservation of political subdivisions. Iowa must also comply with

the federal constitutional requirements which requires that the state's districts must be nearly equal in population. For the plan to be considered, our deviation must be below 1%.

Citations: <https://www.ncsl.org/research/redistricting/redistricting-criteria.aspx>
<http://publications.iowa.gov/135/1/history/7-7.html>
<https://www.legis.iowa.gov/docs/code/2016/42.4.pdf>

PROBLEM STATEMENT:

With the use of OR methods and programming, a new congressional districting plan will be developed for the state of Iowa that will satisfy the necessary principles, laws, and logistic.

INTEGER PROGRAMMING MODEL:

HESS MODEL (COMPACTNESS) & contiguity :

Sets: V is the set of land parcels in Iowa

$$N(i) = \{j \in V \mid \{i, j\} \in E\}$$

Indices: i is a vertex (county)

j is the vertex

Parameters: p_i = population of a parcel

k = number of districts to be created ($k = 4$)

L = lower population bound ($L = 757,781$)

U = upper population bound ($U = 765,396$)

n = the number of land parcels ($n = |V|$)

v = district center

$$w_{ij} = p_i * d_{ij}^2$$

Variables: $x_{ij} = 1$ if vertex i is assigned (to the district centered) at vertex j

0 otherwise

f_{ij}^v = amount of flow, originating at v , that is sent across edge $\{i, j\}$ (from i to j)

Minimize the moment of inertia

$$\min \sum_{i \in V} \sum_{j \in V} w_{ij} x_{ij}$$

Each county i assigned to one district

$$\text{s.t. } \sum_{j \in V} x_{ij} = 1 \quad \forall i \in V$$

k district centers are chosen

$$\sum_{j \in V} x_{jj} = k$$

If j roots a district, then population
is between between L and U

$$Lx_{jj} \leq \sum_{i \in V} p_i x_{ij} \leq Ux_{jj} \quad \forall j \in V$$

If i is assigned to j , then j is a
center

$$x_{ij} \leq x_{jj} \quad \forall i, j \in V$$

Each vertex i is either assigned or not

$$x_{ij} \in \{0, 1\} \quad \forall i, j \in V$$

*Contiguity constraints are implemented below

If vertex i is assigned to center j then
 i consumes one unit of flow of type j
otherwise : no units consumed

$$\sum_{u \in N(i)} (f_{ui}^j - f_{iu}^j) = x_{ij} \quad \forall i \in V \setminus \{j\}, \forall j \in V$$

Vertex i can receive flow of j only if
 i is assigned to center j

$$\sum_{u \in N(i)} f_{ui}^j \leq (n-1)x_{ij} \quad \forall i \in V \setminus \{j\}, \forall j \in V$$

Node j cannot receive flow of its
own type

$$\sum_{u \in N(i)} f_{uj}^i = 0 \quad \forall j \in V$$

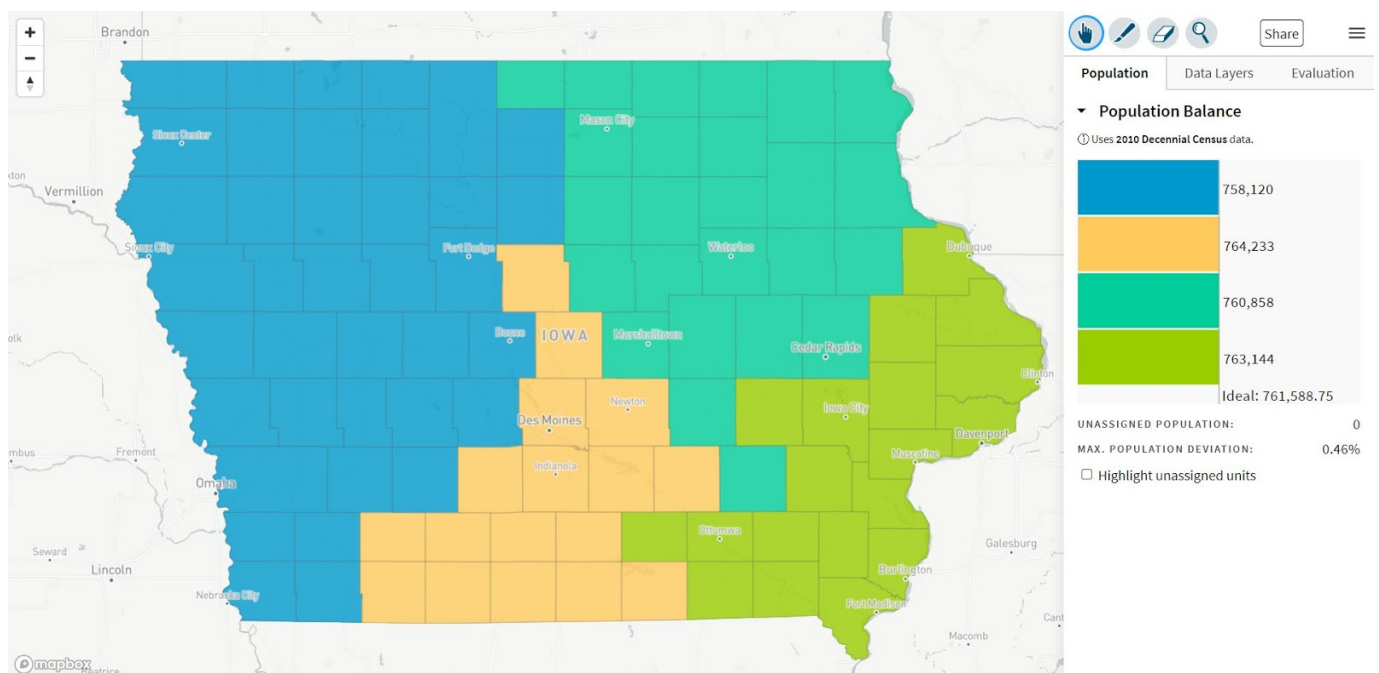
Must be positive

$$f_{ij}^v, f_{ji}^v \geq 0 \quad \forall \{i, j\} \in E, \forall v \in V.$$

EXPERIMENTS:

The laptop we used had a RAM of 64.0GB with 63.8GB being usable. The laptop used a 64-bit operating system with an Intel i7 core and 2.90GHz. The solver version we used was the Gurobi optimizer version 9.1.1 which gave us an objective value of 6.851641139809e+09 with a 0.0000% gap. The model was solved to optimality and was found in 14.44 seconds.

MAP:



The moment of inertia objective is 6851641139.809169

District 0 has population 763144 and contains counties ['Jackson', 'Muscatine', 'Clinton', 'Iowa', 'Washington', 'Johnson', 'Monroe', 'Dubuque', 'Van Buren', 'Jefferson', 'Davis', 'Scott', 'Cedar', 'Des Moines', 'Henry', 'Jones', 'Louisa', 'Wapello', 'Lee']

District 1 has population 758120 and contains counties ['Clay', 'Shelby', 'Wright', 'Buena Vista', 'Woodbury', 'Kossuth', 'Sac', 'Humboldt', 'Cherokee', 'Lyon', 'O'Brien', 'Guthrie', 'Dickinson', 'Plymouth', 'Dallas', 'Palo Alto', 'Fremont', 'Montgomery', 'Webster', 'Calhoun', 'Boone', 'Page', 'Ida', 'Crawford', 'Carroll', 'Audubon', 'Sioux', 'Adair', 'Mills', 'Monona', 'Harrison', 'Emmet', 'Cass', 'Osceola', 'Hancock', 'Pocahontas', 'Greene', 'Pottawattamie']

District 2 has population 760858 and contains counties ['Marshall', 'Benton', 'Clayton', 'Worth', 'Winnebago', 'Keokuk', 'Franklin', 'Floyd', 'Black Hawk', 'Mitchell', 'Butler', 'Linn', 'Delaware', 'Hardin', 'Buchanan', 'Chickasaw', 'Allamakee', 'Cerro Gordo', 'Fayette', 'Bremer', 'Tama', 'Poweshiek', 'Winnebago', 'Grundy', 'Howard']

District 3 has population 764233 and contains counties ['Hamilton', 'Taylor', 'Marion', 'Appanoose', 'Clarke', 'Ringgold', 'Warren', 'Decatur', 'Mahaska', 'Jasper', 'Adams', 'Union', 'Wayne', 'Lucas', 'Polk', 'Madison', 'Story']

EVALUATION OF PLAN:

The proposed map meets all of Iowa's prohibited and required criteria as seen in the plan above. The map exhibits a 0.46% error which is below the 1% deviation range. The map reveals the population balance in a compact, continuous, and subdivision-preserved manner. Some limitations of our plan include unforeseeable errors or recent population changes. The data imported into the program presented population data from 2018, which could be more or less than the Iowa population in 2021.

CONCLUSION:

Our plan concluded that the state of Iowa could be divided into 4 distinct districts with a 0.46% error in population. With the imposition of the required criteria, we were able to produce a fair and consistent map.