

# **Congressional Districting Project: Iowa**

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## Executive Summary Letter

The main purpose of this project is to create an LP model that will redistrict the congressional map of the state of Iowa using Python and Gurobipy. To do this, our team had to take into consideration both federal and state requirements to define the districts.

The model consists on using the 2020 Iowa census data of each county population, and each county's distance to other county. The model minimized the relationship between the dimension of each county squared with its population. We subjected the minimization function to the federal and state requirements to make sure the redistricting process stays legal.

This project is presented as:

- A mathematical model.
- A word explanation behind the math model
- A Python code running the optimization model.

This approach helps understand each part of the problem and finding a best optimal solution to redistrict the state of Iowa.

## Introduction

### Congressional Redistricting

At a federal level, it is authorized by the United States Constitution to redistrict with certain conditions. The main priority is to ensure that the districts are not hard to identify, guarantee fairness and consistency, and avoid any confusion. One condition stated by the

federal government is that all districts must have a roughly similar population size. If the largest and smallest districts have a difference of more than ten percent, then it is considered suspicious. Another important criteria stated by the United States Constitution is to discriminate against a district based on the dominant race in the district. In addition to the federal criteria, each state has the authority to include additional criteria.

## **Criteria**

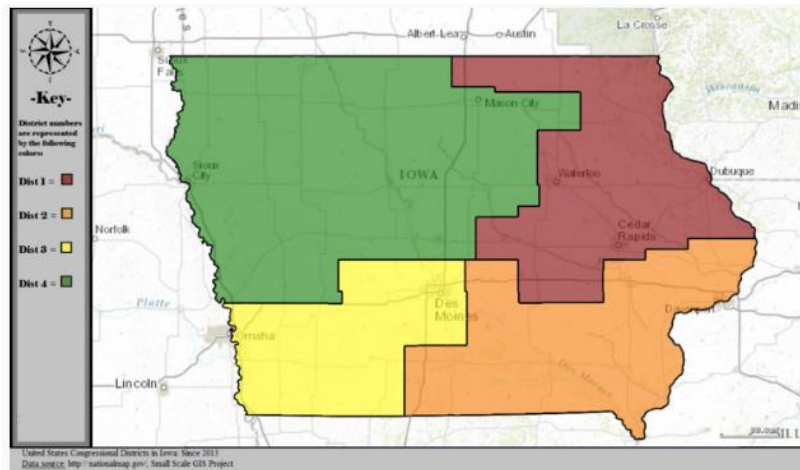
In Iowa, there are some required and prohibited criteria for redistricting. Here are the criteria stated by Iowa:

1. The state of Iowa requires a minimum distance between all parts of a constituency, in other words, compactness. To measure the district's compactness is the absolute value of the difference between the length and the width of the district. Basically, compare the northernmost point with the southernmost point and the easternmost point with the westernmost point. Iowa also considers the perimeter compactness.
2. Besides compactness, Iowa requires all parts of the district to relate to the rest of the district. (Contiguity). Corners adjoining is not considered contiguous.
3. Iowa requires the preservation of counties and other political subdivisions. This means that district boundaries shall coincide with the boundaries of political subdivisions of the state districts; therefore, when redistricting, the new districts shall not cross counties, cities, or towns.

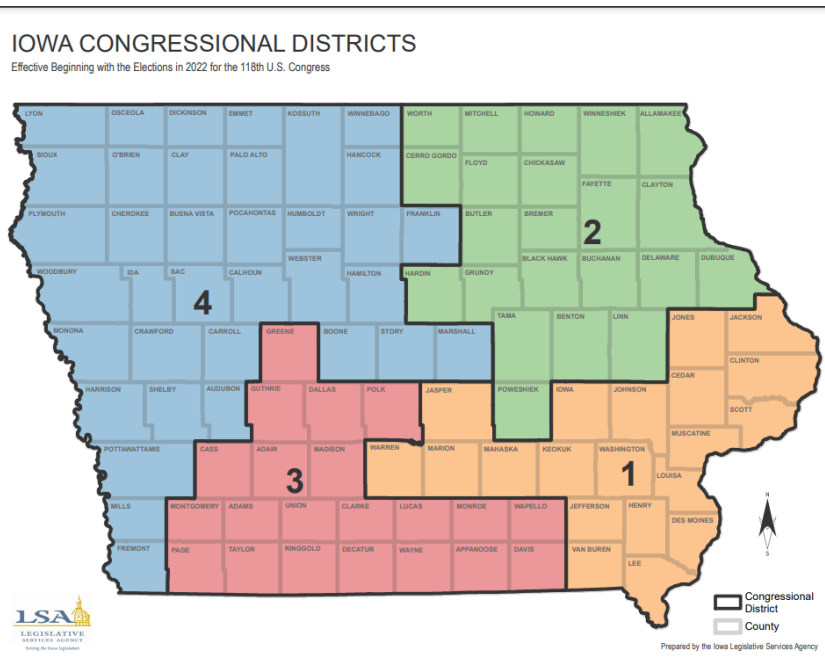
On the other side, there are some criteria that the state of Iowa prohibits:

Now that we know what Iowa requires for redistricting plans, let us look at Iowa's districts from previous apportionments.

- In 2010, Iowa lost congressional district seat, going from 5 in 2000, to 4 in 2010.



- In 2020, there were minimal changes in Iowa's congressional district. It remained at 4.



## Problem Statement

The objective of the project is to redistrict the congressional map as compact as possible without failing to stick to the law. Since one of Iowa's requirements is to respect all counties, we use whole counties' populations and dimensions. Since counties are very important geographical and political divisions, it is important to respect each one of them as a whole and do not cut through one of them when redistricting.

## Operations Research Model (In Words)

As stated previously, our model's objective function that we are trying to seek is a minimization function, the function will achieve the desired population in each of the four districts, taking care of the counties as a parameter. This model focuses on assigning counties to districts based on both the population size and the compactness. The exact operation that the function will perform will be multiplying the square county's dimension with the county's population if that county is assigned to the district.

There are three different sets of constraints:

1. **Assignment Constraint:** This part of the model makes sure that each county is assigned to a district. We do not want any counties to miss out on a district. This constraint sums every county assigned for every county inside the state to ensure that the sum is not equal to zero.
2. **Population Constraint:** Since the most important redistricting requirement is population consistency without exceeding the range of 1% (+/-0.5%) for population deviation, our team started by calculating the permitted range of 1%(+/-0.5%) for population deviation. Then, set those as lower and upper parameters. The constraint

ensures that the assigned county population's sum does not exceed the upper and lower population limits.

3. **District Constraint:** This constraint makes sure that the number of districts (in this case, four) is respected by all the counties. It is important to respect the number of districts assigned to each state. Iowa cannot have less or more than four districts.

Another relevant constraint to mention is that the county assigned to a certain district cannot be greater than the county assigned as the center of the district.

## Operations Research Model (in math)

### Sets:

- $C = \{1, 2, \dots, 99\}$ . The set of counties inside Iowa.
- $K = \{1, 2, 3, 4\}$ . The set of districts in Iowa.

### Indices:

- $i$  as a county, where  $(i \in C)$
- $j$ , as a district where  $(j \in K)$

### Parameters:

- $p_i$  = The population of county  $i$ .
- $d_i$  = The dimension of county  $i$ .
- $k$  = Number of districts
- $U$  = Upper Population Bound
- $L$  = Lower Population Bound

### Calculating the population bounds:

Iowa population = 3,190,369

$$0.995 * \frac{\text{Total population}}{k} \leq \text{District Population} \leq 1.005 * \frac{\text{Total population}}{k}$$

$$0.995 * \frac{3,190,369}{4} \leq \text{District Population} \leq 1.005 * \frac{3,190,369}{4}$$

$$793,604 \leq \text{District Population} \leq 801,580$$

$$\therefore U = 801,580 \text{ \& } L = 793,604.$$

Decision Variables:

$$x_{ij} = \begin{cases} 1; & \text{if county } i \text{ is assigned to district } j \\ 0; & \text{Otherwise} \end{cases}$$

## Objective Function

Minimize:

$$\sum_{i \in C} \sum_{j \in K} p_i d_{ij}^2 x_{ij}$$

**Constraints:**

$$\sum_{j \in C} x_{jj} = k = 4.$$

$$\sum_{j \in C} x_{ij} = 1 \quad \forall i \in C.$$

$$x_{ij} \leq x_{jj}.$$

$$L \leq \sum_{i \in C} p_i x_{ij} \leq U \quad \forall j \in K.$$

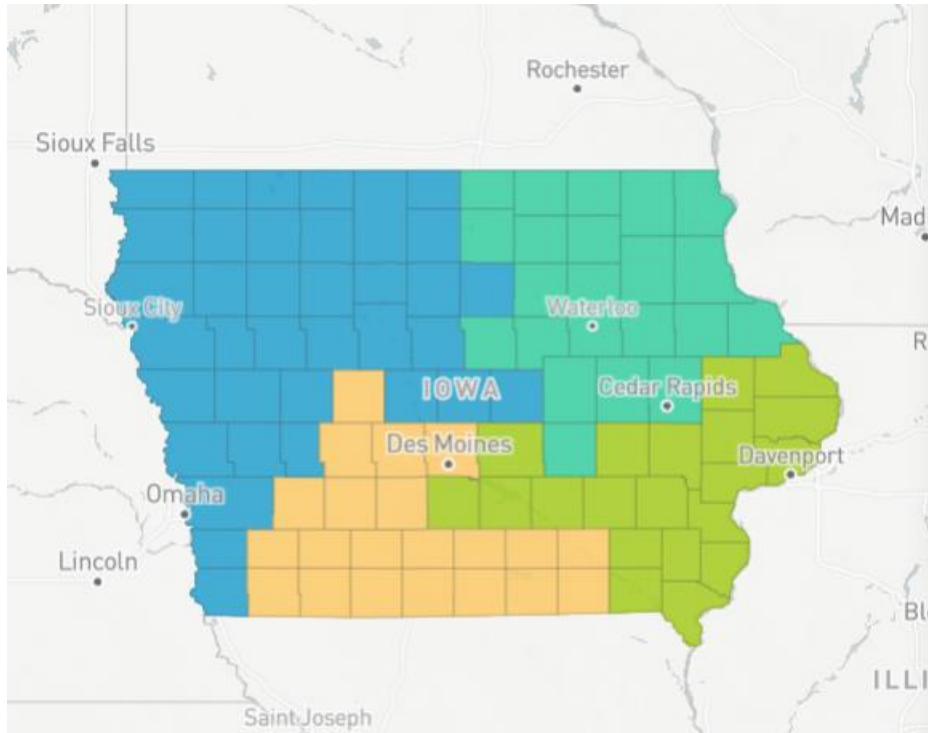
## Experiments

The model was run in a 2021 Dell Inspiron 7506 2n1 Laptop with:

- Windows 10 Pro, 64-bit
- Processor Speed Up to 4.2 GHz
- RAM: 16 GB

We used Python in JupyterLab from Anaconda as our choice of programming language since we could export Gurobipy Optimizer Version 11.0.0 and use it to solve the model. It took Gurobi less than two seconds to run the program.

## Plan and Map



District 1: 797,645

District 2: 797,551

District 3: 797,589



District 4: 797,584

## **Evaluation of Plan**

In order for a map to work, it must meet all criteria. The model proposed meets all the requirements stated by federal and state law. Since most of Iowa's population is mainly located in the center of the State, that is why the center is divided into different districts. It is important to mention the capitol Des Moines is the most populated city in Iowa, that is why the county it belongs to is the smallest one from all four. On the other side, the largest district is made of mainly small towns and villages, since there are no big populations concentrated in the northwestern side of Iowa. This map meets all the criteria.

## **Conclusions**

We have seen how Operations Research is useful in many things. It helped us find an optimal solution to separate the counties into different districts. Since Iowa's population growth is focused on its main cities like Des Moines, Cedar Rapids, or Iowa City, this model could work for a couple of years. After the expected migration from other states plus the natural population growth, we expect that in the future the districts containing relevant cities population wise will lose districts and will be part of districts with less cities. Hopefully, with this new plan, Iowa could use redistricting as an opportunity to provide citizens with a fair vote and a strong voice in the future of the state.

## **GitHub Repository**

**<https://github.com/emiliors/Iowa-Redistricting.git>**

## Works Cited

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