

IE 5318 Principles of Operation Research

TEAM PROJECT

STATE: New Mexico

Project: Congressional Redistricting in New Mexico

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Executive Summary

In this project, we will be examining the counties of New Mexico and redistricting them according to Federal and State legislation. New Mexico has 3 districts and 33 counties. New Mexico is the fifth largest by area of the fifty states but with just over 2.1 million residents. Redistricting is necessary to ensure population equality and to prevent dilution of minority voting strength, as required by law. (Service, 2001) This research aims to provide a fresh approach to New Mexico's redistricting process. The prerequisites include adhering to all relevant federal and state laws and regulations. In addition, the team wanted to prevent any kind of gerrymandering that might negatively impact voting groups and to limit the greatest population difference across districts to less than 1%. To prevent prejudice, the research team employed an entirely mathematical method to identify the optimal districts, ignoring the state's voting habits. The Labelling Model is the name of the mathematical technique that was applied to find the most compact districts that might exist. To achieve compactness, this strategy effectively reduces the number of boundaries between districts. In the example below, lines are drawn between counties that share a boundary, and each of the 16 dots represents a separate county. (For instance, counties 2, 5, 7, and 10 share borders with county 6.) A cut edge occurs when a district's boundary coincides with a county's border, placing two adjacent counties in separate districts.

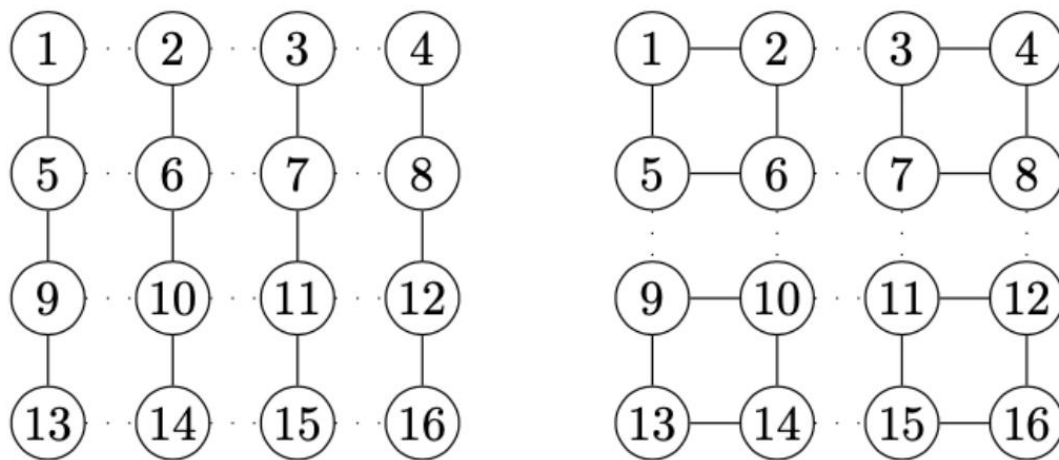


Figure 1 Distribution Modelling

The Labelling Model indicates that the least compact arrangement of the districts is seen in Figure 1, where the four districts produce 12 cut edges. Conversely, Figure 2 is the most compact district arrangement for this collection of counties based on the labelling model as it only generates 8 cut edges with the same number of districts. This model was enlarged and utilized to find the most condensed configuration for New Mexico's three congressional districts.

Introduction

The act of redrawing political districts on a map to ascertain whether voters would support the same group of candidates is known as redistricting. In the United States, the government obtains statistics about the inhabitants of certain areas every 10 years during the census. Redistricting will be necessary in the state if one district's population is excessively higher than that of the other districts. Redistricting is a procedure with numerous potential outcomes, and it has often been used to gerrymander—that is, to create districts in a way that favors or disadvantages particular political candidates or parties. Additionally, gerrymandering can be utilized to increase or decrease the influence of voting groupings. For instance, to reduce the voting strength of a group of black people, the person drawing the district boundaries can divide them up over many districts. To ensure as fair an electoral process as possible, this report's objective is just the opposite. The project team worked hard to ensure that all voter groups had equal representation in each district and that the population distribution was as even as feasible.

New Mexico Redistricting Criteria

When establishing new congressional districts, several state and federal requirements must be fulfilled. These are taken from the New Mexico State Legislative Council, the Voting Rights Act of 1965, and the United States Constitution. The project team's new proposals for plans must abide by every one of these regulations; any plan that does not must be rejected.

United States Federal Requirements:

According to Article I, Section 2 of the U.S. Constitution's Apportionment Clause, every district's population must be as close to equal as possible:

“Representatives and direct Taxes shall be apportioned among the several States which may be included within this Union, according to their respective Numbers, which shall be determined by adding to the whole Number of free Persons, including those bound to Service for a Term of Years, and excluding Indians not taxed, three-fifths of all other Persons.”

Plans that might reduce the minority vote due to intentional or inadvertent racial discrimination are forbidden under Section 2 of the Voting Rights Act of 1965:

“No voting qualification or prerequisite to voting, or standard, practice, or procedure shall be imposed or applied by any State or political subdivision to deny or abridge the right of any citizen of the United States to vote on account of race or color.”

New Mexico State Requirements:

The New Mexico State Legislative Council decided to employ the following criteria when creating a congressional redistricting plan using data from the 2010 Census:

- 1) The population of each congressional district must be as equal as is practical.
- 2) The United States Bureau of the Census produced data from the 2010 federal decennial census, which the legislature will use.
- 3) Every redistricting scheme must only use districts with one member.
- 4) Since a precinct is an essential component of a voting district in New Mexico, districts that split precincts should not be included in any proposed redistricting plans that the legislature takes into consideration.
- 5) The drawing of districts must adhere to established districting standards. Districts must consist of suitably compact precincts that are adjacent to one another. Districts will be created, if possible, to maintain communities of interest and must be cognizant of geographical and political limits. The legislature might also consider incumbents' residences and attempt to maintain the core of current districts to the greatest degree possible.
- 6) Plans must adhere to federal constitutional requirements as well as the restrictions of the Voting Rights Act of 1965, as modified. Plans that weaken the voting power of a protected minority are not acceptable. When creating redistricting plans, race may be considered, but it shouldn't be the primary factor. Racial concerns should not take precedence over the traditional race-neutral districting standards (as stated in paragraph seven).

Current Districts

There are three congressional districts in the state of New Mexico. Here are the congressional districts:

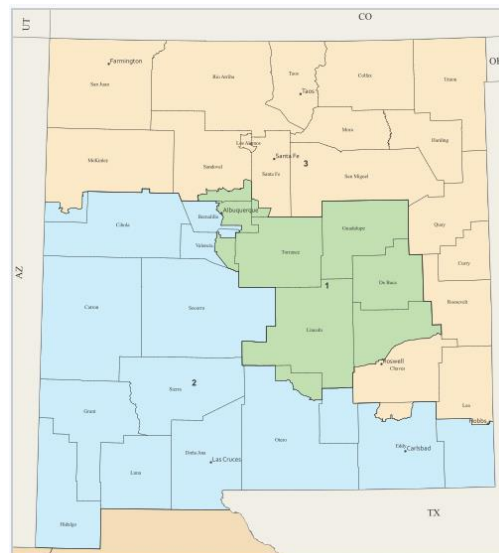


Figure 2 New Mexico present county distribution

Compactness, contiguity, preservation of communities of importance, and preservation of the cores of former districts are all met by New Mexico. The 2010 Redistricting Divergence Table indicates that New Mexico's population divergence as of right now is 0.0%.

To maintain a 1% population deviation, the population limits would need to stay within the range of 682,961 and 689,825 using the statistics from the 2010 census. In reality, New Mexico still maintains its redistricting data at nmlegis.gov.

Operation Research Model

Sets: The New Mexico County set is denoted by C .

Indices: 'I' is a New Mexico County.

'J' is a New Mexico district.

Setting parameters is the county's population.

'K' is the number of districts ($k=3$).

'L' is the district having the least number of residents.

'U' denotes the most populous district.

$$\text{Variables: } x_{ij} = \begin{cases} 1 & \text{if county } i \text{ is assigned to district } j \text{ (} i \in C \text{ and } j \in \{1,2,3\}) \\ 0 & \text{otherwise} \end{cases}$$

$$y_e = \begin{cases} 1 & \text{if edge } e \in E \text{ is cut} \\ 0 & \text{otherwise} \end{cases}$$

r_{ij} = a root of a county assigned to a specific district

f_{ij} = the flow of giving a county assigned to a specific district

Minimize the total amount of cut edges	$\text{Min } \sum_{e \in E} y_e$
Make edge $e = \{u, v\}$ cut when vertex u is assigned to district j	subject to: $x_{uj} - x_{vj} \leq y_e \quad \forall e = \{u, v\} \in E, \forall j \in \{1, 2, 3, \dots, k\}$
Make each vertex $i \in V$ assigned to a singular district	$\sum_{j=1}^k x_{ij} = 1 \quad \forall i \in V$
Make the population of each district between parameters L	$L \leq \sum_{i \in C} p_i \leq U \quad \forall j \in \{1, 2, 3, \dots, k\}$

and U		
Each county is assigned to a specific district and every cut edge is either 0 or 1	$x_{ij} \in \{0,1\}$ $y_e \in \{0,1\}$	$\forall i \in V, \forall j \in \{1,2,3, \dots, k\}$ $\forall e \in E$
Make every district have a singular root	$\sum_{i \in V} r_{ij} = 1$	$\forall j \in \{1,2,3, \dots, k\}$
Vertex $i \in V$ must not root to any district j	$r_{ij} \leq x_{ij}$	$\forall i \in V, \forall j \in \{1,2, \dots, k\}$
Make vertex i consume flow when it is not a root	$\sum_{u \in N(i)} (f_{ui} - f_{iu}) \geq 1 - M \sum_{j=1}^k r_{ij} \quad \forall i \in V$	
Prevent flow across cut edges	$f_{ij} + f_{ji} \leq M (1 - y_e)$	$\forall e = \{i, j\} \in E$
Make the flow a nonnegative value	$f_{ij}, f_{ji} \geq 0$	$\forall \{i, j\} \in E$
Make each root either 0 or 1	$r_{ij} \in \{0,1\}$	$\forall i \in V, \forall j \in \{1,2, \dots, k\}.$

Description of OR Model

The goal of the integer program is to reduce the overall number of cut edges. The constraints are:

- 1) Each county is assigned to a certain district, which is one of the program's problems.
- 2) Designate a district for every vertex.
- 3) Establish a population range of L to U in each district.
- 4) Designate each county to a separate district, with each cut edge having a value of 0 or 1.
- 5) Distribute a single root to each district.
- 6) If the flow is not allocated to a root, assign a vertex to a county so that it can be consumed.
- 7) Designate trimmed edges as non-flowing.
- 8) Flow must have a positive value.
- 9) Designate a root's value as either 0 or 1.

Problem Statement

The task presented is to create a congressional districting scheme that complies with both state and federal regulations and can survive judicial examination. The goal is to reduce the disparity in population between the districts with the highest and lowest populations. The limitations imposed on the counties are as follows: each county will be assigned to one of the three districts; each district's population will be between the lowest and highest population of a Congressional District; and each county will be forced to associate with a specific district or not (i.e., involve the entire county population or not). When calculating a county's population to create a Congressional District, counties will remain entire.

Experiment Discussion

The Gourbi Optimizer version 10.0.3 build v10.0.3rc0 (win64) Jupyter Notebook was used to write, assemble, and solve the optimization model. Anaconda was the programming language utilized. The model was operated on a Dell G15 Gaming Laptop with a 12th Gen Intel(R) Core (TM) i5-12500H, instruction set [SSE2|AVX|AVX2] CPU running at 2.20GHz and 16.0 GB of RAM. Cutting-edge software with geopandas and contiguity is being employed. Although the moment of inertia and perimeter programs were also evaluated, the cut edges better reflected the intended outcome. The model was solved by the software in a very short time, although the solution time was noted in the final solving time as 0.01s

Map and Plan

Here is our suggested course of action:

District 1

The counties of Cibola and Bernalillo will make up this district.

District 2

will comprise the following counties: De Baca, Doña Ana, Chaves, Valencia, Catron, Socorro, Lincoln, Luna, Grant, Otero, Roosevelt, Eddy, and Eddy.

District 3

will comprise the following counties: Rio Arriba, San Miguel, Sandoval, Santa Fe, McKinley, Mora, Harding, Guadalupe, San Juan, Curry, Taos, Quay, Colfax, Los Alamos, and Union counties.

Each district has a population of 689,777, 685,630, and 683,772, in that order. This map of New Mexico illustrates the design; District 1 is depicted in yellow, District 2 is shown in blue, and District 3 is shown in green.

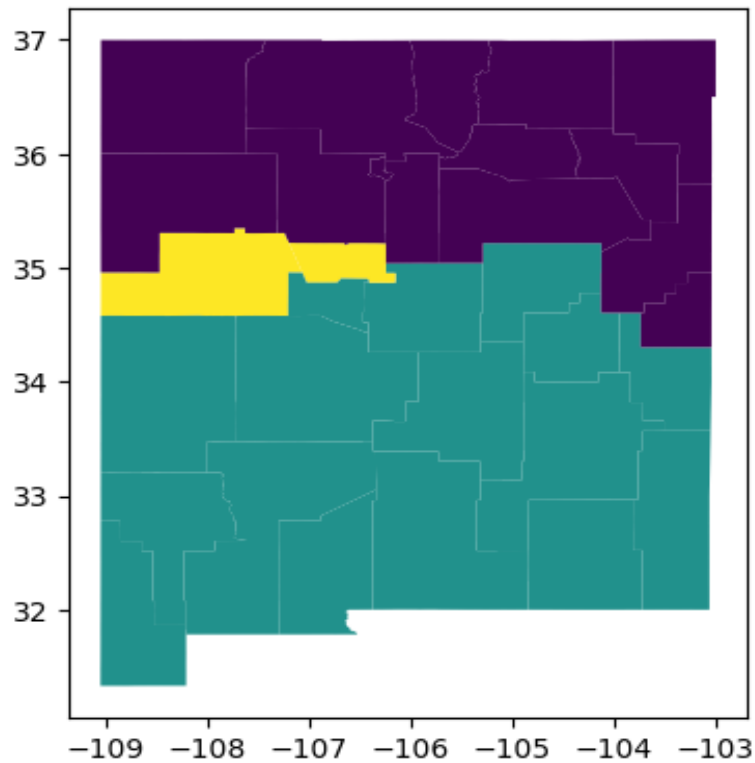


Figure 3 New distribution of New Mexico

Evaluation of Proposed Redistricting Plan

The requirements established by the state of New Mexico and the federal government of the United States are both adequately met by this plan. At less than half a percent or 0.49%, there is the largest population divergence between the most inhabited district (District 2) and the least populated district (District 1). Only county-level district divides are made in this plan; racial discrimination, political subdivisions, or communities of interest are not included. In addition, the strategy maintains the cores of the previous districts, makes for very tight districts, and avoids drawing new boundaries that would force the incumbents to leave their present districts.

However, there are several limitations to the suggested method. Since none of the project team members live in the state of New Mexico, they have little firsthand understanding of the region and the local populations. While this makes the statistical model that was used to form the districts neutral in certain ways, it also has limitations since it ignores voting trends and subcommunities, which raises the possibility of inadvertently gerrymandering the state.

Conclusion

The ideal three districts—with populations of 689,777, 685,630, and 683,772—have been established using a labeling model and a cut-edge program. Both the top and lower limits of the maximum population deviation stay below 5%, and the model satisfies both state and federal requirements. The study team suggests that to reduce population divergence and increase district compactness, the state of New Mexico should implement this districting plan.

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