

Assign2_final

November 13, 2023

```
[12]: import pandas as pd
import numpy as np
import pulp
from itertools import chain, combinations
import statistics as stats
import matplotlib.pyplot as plt
import seaborn as sns

counties_df = pd.read_csv('data/uscounties_geo.csv', header=0)
counties_df = counties_df[counties_df['state_id'] == 'WA'].
    ↪reset_index(drop=True)
counties_df
```

```
[12]:
```

	county	county_ascii	county_full	county_fips	state_id	\
0	King	King	King County	53033	WA	
1	Pierce	Pierce	Pierce County	53053	WA	
2	Snohomish	Snohomish	Snohomish County	53061	WA	
3	Spokane	Spokane	Spokane County	53063	WA	
4	Clark	Clark	Clark County	53011	WA	
5	Thurston	Thurston	Thurston County	53067	WA	
6	Kitsap	Kitsap	Kitsap County	53035	WA	
7	Yakima	Yakima	Yakima County	53077	WA	
8	Whatcom	Whatcom	Whatcom County	53073	WA	
9	Benton	Benton	Benton County	53005	WA	
10	Skagit	Skagit	Skagit County	53057	WA	
11	Cowlitz	Cowlitz	Cowlitz County	53015	WA	
12	Grant	Grant	Grant County	53025	WA	
13	Franklin	Franklin	Franklin County	53021	WA	
14	Island	Island	Island County	53029	WA	
15	Lewis	Lewis	Lewis County	53041	WA	
16	Chelan	Chelan	Chelan County	53007	WA	
17	Clallam	Clallam	Clallam County	53009	WA	
18	Grays Harbor	Grays Harbor	Grays Harbor County	53027	WA	
19	Mason	Mason	Mason County	53045	WA	
20	Walla Walla	Walla Walla	Walla Walla County	53071	WA	
21	Whitman	Whitman	Whitman County	53075	WA	
22	Stevens	Stevens	Stevens County	53065	WA	

23	Kittitas	Kittitas	Kittitas County	53037	WA
24	Douglas	Douglas	Douglas County	53017	WA
25	Okanogan	Okanogan	Okanogan County	53047	WA
26	Jefferson	Jefferson	Jefferson County	53031	WA
27	Pacific	Pacific	Pacific County	53049	WA
28	Klickitat	Klickitat	Klickitat County	53039	WA
29	Asotin	Asotin	Asotin County	53003	WA
30	Adams	Adams	Adams County	53001	WA
31	San Juan	San Juan	San Juan County	53055	WA
32	Pend Oreille	Pend Oreille	Pend Oreille County	53051	WA
33	Skamania	Skamania	Skamania County	53059	WA
34	Lincoln	Lincoln	Lincoln County	53043	WA
35	Ferry	Ferry	Ferry County	53019	WA
36	Wahkiakum	Wahkiakum	Wahkiakum County	53069	WA
37	Columbia	Columbia	Columbia County	53013	WA
38	Garfield	Garfield	Garfield County	53023	WA

	state_name	lat	lng	population
0	Washington	47.4902	-121.8052	2240876
1	Washington	47.0241	-122.1046	910225
2	Washington	48.0475	-121.6975	820024
3	Washington	47.6207	-117.4040	531477
4	Washington	45.7792	-122.4825	496494
5	Washington	46.9258	-122.8332	290642
6	Washington	47.6130	-122.6716	273072
7	Washington	46.4571	-120.7385	255151
8	Washington	48.8259	-121.7199	224533
9	Washington	46.2398	-119.5112	204551
10	Washington	48.4794	-121.7302	128228
11	Washington	46.1932	-122.6810	109457
12	Washington	47.2057	-119.4518	97874
13	Washington	46.5347	-118.8990	95313
14	Washington	48.1630	-122.5481	85938
15	Washington	46.5778	-122.3927	81214
16	Washington	47.8692	-120.6190	78508
17	Washington	48.0493	-123.9280	76727
18	Washington	47.1503	-123.7735	74737
19	Washington	47.3484	-123.1927	64964
20	Washington	46.2298	-118.4784	62168
21	Washington	46.9012	-117.5230	48197
22	Washington	48.3991	-117.8552	46057
23	Washington	47.1244	-120.6798	44147
24	Washington	47.7361	-119.6918	42622
25	Washington	48.5488	-119.7408	41966
26	Washington	47.7487	-123.5960	32590
27	Washington	46.5557	-123.7041	22974
28	Washington	45.8738	-120.7891	22478

29	Washington	46.1918	-117.2030	22285
30	Washington	46.9834	-118.5606	20353
31	Washington	48.5782	-122.9650	17631
32	Washington	48.5323	-117.2740	13302
33	Washington	46.0230	-121.9147	11973
34	Washington	47.5763	-118.4187	10798
35	Washington	48.4703	-118.5166	7198
36	Washington	46.2918	-123.4244	4373
37	Washington	46.2975	-117.9078	3969
38	Washington	46.4316	-117.5452	2278

```
[13]: districts_df= pd.read_csv('data/county_districts.csv', header=0)
districts_df['county']=districts_df['county'].str.lstrip(' ').str.rstrip(' ')
counties_df['county']=counties_df['county'].str.lstrip(' ').str.rstrip(' ')
counties_df=counties_df.merge(districts_df, on='county', how='left')
counties_df
```

```
[13]:
```

	county	county_ascii	county_full	county_fips	state_id	\
0	King	King	King County	53033	WA	
1	Pierce	Pierce	Pierce County	53053	WA	
2	Snohomish	Snohomish	Snohomish County	53061	WA	
3	Spokane	Spokane	Spokane County	53063	WA	
4	Clark	Clark	Clark County	53011	WA	
5	Thurston	Thurston	Thurston County	53067	WA	
6	Kitsap	Kitsap	Kitsap County	53035	WA	
7	Yakima	Yakima	Yakima County	53077	WA	
8	Whatcom	Whatcom	Whatcom County	53073	WA	
9	Benton	Benton	Benton County	53005	WA	
10	Skagit	Skagit	Skagit County	53057	WA	
11	Cowlitz	Cowlitz	Cowlitz County	53015	WA	
12	Grant	Grant	Grant County	53025	WA	
13	Franklin	Franklin	Franklin County	53021	WA	
14	Island	Island	Island County	53029	WA	
15	Lewis	Lewis	Lewis County	53041	WA	
16	Chelan	Chelan	Chelan County	53007	WA	
17	Clallam	Clallam	Clallam County	53009	WA	
18	Grays Harbor	Grays Harbor	Grays Harbor County	53027	WA	
19	Mason	Mason	Mason County	53045	WA	
20	Walla Walla	Walla Walla	Walla Walla County	53071	WA	
21	Whitman	Whitman	Whitman County	53075	WA	
22	Stevens	Stevens	Stevens County	53065	WA	
23	Kittitas	Kittitas	Kittitas County	53037	WA	
24	Douglas	Douglas	Douglas County	53017	WA	
25	Okanogan	Okanogan	Okanogan County	53047	WA	
26	Jefferson	Jefferson	Jefferson County	53031	WA	
27	Pacific	Pacific	Pacific County	53049	WA	
28	Klickitat	Klickitat	Klickitat County	53039	WA	

29	Asotin	Asotin	Asotin County	53003	WA
30	Adams	Adams	Adams County	53001	WA
31	San Juan	San Juan	San Juan County	53055	WA
32	Pend Oreille	Pend Oreille	Pend Oreille County	53051	WA
33	Skamania	Skamania	Skamania County	53059	WA
34	Lincoln	Lincoln	Lincoln County	53043	WA
35	Ferry	Ferry	Ferry County	53019	WA
36	Wahkiakum	Wahkiakum	Wahkiakum County	53069	WA
37	Columbia	Columbia	Columbia County	53013	WA
38	Garfield	Garfield	Garfield County	53023	WA

	state_name	lat	lng	population	District
0	Washington	47.4902	-121.8052	2240876	7
1	Washington	47.0241	-122.1046	910225	10
2	Washington	48.0475	-121.6975	820024	1
3	Washington	47.6207	-117.4040	531477	5
4	Washington	45.7792	-122.4825	496494	3
5	Washington	46.9258	-122.8332	290642	10
6	Washington	47.6130	-122.6716	273072	6
7	Washington	46.4571	-120.7385	255151	4
8	Washington	48.8259	-121.7199	224533	1
9	Washington	46.2398	-119.5112	204551	4
10	Washington	48.4794	-121.7302	128228	2
11	Washington	46.1932	-122.6810	109457	3
12	Washington	47.2057	-119.4518	97874	4
13	Washington	46.5347	-118.8990	95313	4
14	Washington	48.1630	-122.5481	85938	2
15	Washington	46.5778	-122.3927	81214	3
16	Washington	47.8692	-120.6190	78508	8
17	Washington	48.0493	-123.9280	76727	6
18	Washington	47.1503	-123.7735	74737	6
19	Washington	47.3484	-123.1927	64964	6
20	Washington	46.2298	-118.4784	62168	5
21	Washington	46.9012	-117.5230	48197	5
22	Washington	48.3991	-117.8552	46057	5
23	Washington	47.1244	-120.6798	44147	8
24	Washington	47.7361	-119.6918	42622	8
25	Washington	48.5488	-119.7408	41966	4
26	Washington	47.7487	-123.5960	32590	6
27	Washington	46.5557	-123.7041	22974	6
28	Washington	45.8738	-120.7891	22478	3
29	Washington	46.1918	-117.2030	22285	5
30	Washington	46.9834	-118.5606	20353	4
31	Washington	48.5782	-122.9650	17631	2
32	Washington	48.5323	-117.2740	13302	5
33	Washington	46.0230	-121.9147	11973	3
34	Washington	47.5763	-118.4187	10798	5

35	Washington	48.4703	-118.5166	7198	5
36	Washington	46.2918	-123.4244	4373	3
37	Washington	46.2975	-117.9078	3969	5
38	Washington	46.4316	-117.5452	2278	5

```
[14]: ## white only census
census_df = pd.read_csv('data/census_demographics.csv', header=0)
census_df['WA_MALE']=pd.to_numeric(census_df['WA_MALE'])
census_df['WA_FEMALE']=pd.to_numeric(census_df['WA_FEMALE'])
census_df['WHITE_POP']=census_df['WA_MALE']+census_df['WA_FEMALE']
census_df = census_df.groupby(['COUNTY', 'CTYNAME'])[['TOT_POP', 'WHITE_POP']].
    ↪sum().reset_index()
census_df['CTYNAME']=census_df['CTYNAME'].str.lstrip(' ').str.rstrip(' ')
census_df
```

```
[14]:
```

	COUNTY	CTYNAME	TOT_POP	WHITE_POP
0	1	Adams County	165642	145704
1	3	Asotin County	179178	165888
2	5	Benton County	1675328	1501572
3	7	Chelan County	636014	591962
4	9	Clallam County	621528	537626
5	11	Clark County	4075954	3474526
6	13	Columbia County	31884	28776
7	15	Cowlitz County	890726	806168
8	17	Douglas County	347996	320036
9	19	Ferry County	58178	44344
10	21	Franklin County	781386	699244
11	23	Garfield County	18606	17062
12	25	Grant County	800596	730156
13	27	Grays Harbor County	610632	529248
14	29	Island County	696038	591440
15	31	Jefferson County	266376	242286
16	33	King County	18127176	11714772
17	35	Kitsap County	2211342	1814044
18	37	Kittitas County	357690	327504
19	39	Klickitat County	183998	170452
20	41	Lewis County	669306	613284
21	43	Lincoln County	89368	83150
22	45	Mason County	534292	465360
23	47	Okanogan County	340224	278120
24	49	Pacific County	189880	170762
25	51	Pend Oreille County	109990	99738
26	53	Pierce County	7398480	5417388
27	55	San Juan County	145786	136596
28	57	Skagit County	1043022	939068
29	59	Skamania County	97466	86544
30	61	Snohomish County	6667864	5015430

31	63	Spokane County	4351290	3850124
32	65	Stevens County	377638	337208
33	67	Thurston County	2375242	1919370
34	69	Wahkiakum County	36258	33076
35	71	Walla Walla County	498506	454124
36	73	Whatcom County	1823336	1565160
37	75	Whitman County	373264	312788
38	77	Yakima County	2054138	1779572

```
[15]: # the strings arent joining but I can sort and join on the index
counties_df=counties_df.sort_values(by=['county']).reset_index(drop=True)
census_df=census_df.sort_values(by=['CTYNAME']).reset_index(drop=True)
counties_df=counties_df.merge(census_df, left_index=True, right_index=True,
    how='left')
for i,j in zip( census_df['CTYNAME'].to_list(), counties_df['county'].
    to_list()):
    print(i, ' ', j)

counties_df
```

Adams County	Adams
Asotin County	Asotin
Benton County	Benton
Chelan County	Chelan
Clallam County	Clallam
Clark County	Clark
Columbia County	Columbia
Cowlitz County	Cowlitz
Douglas County	Douglas
Ferry County	Ferry
Franklin County	Franklin
Garfield County	Garfield
Grant County	Grant
Grays Harbor County	Grays Harbor
Island County	Island
Jefferson County	Jefferson
King County	King
Kitsap County	Kitsap
Kittitas County	Kittitas
Klickitat County	Klickitat
Lewis County	Lewis
Lincoln County	Lincoln
Mason County	Mason
Okanogan County	Okanogan
Pacific County	Pacific
Pend Oreille County	Pend Oreille
Pierce County	Pierce
San Juan County	San Juan

Skagit County	Skagit
Skamania County	Skamania
Snohomish County	Snohomish
Spokane County	Spokane
Stevens County	Stevens
Thurston County	Thurston
Wahkiakum County	Wahkiakum
Walla Walla County	Walla Walla
Whatcom County	Whatcom
Whitman County	Whitman
Yakima County	Yakima

[15]:	county	county_ascii	county_full	county_fips	state_id	\
0	Adams	Adams	Adams County	53001	WA	
1	Asotin	Asotin	Asotin County	53003	WA	
2	Benton	Benton	Benton County	53005	WA	
3	Chelan	Chelan	Chelan County	53007	WA	
4	Clallam	Clallam	Clallam County	53009	WA	
5	Clark	Clark	Clark County	53011	WA	
6	Columbia	Columbia	Columbia County	53013	WA	
7	Cowlitz	Cowlitz	Cowlitz County	53015	WA	
8	Douglas	Douglas	Douglas County	53017	WA	
9	Ferry	Ferry	Ferry County	53019	WA	
10	Franklin	Franklin	Franklin County	53021	WA	
11	Garfield	Garfield	Garfield County	53023	WA	
12	Grant	Grant	Grant County	53025	WA	
13	Grays Harbor	Grays Harbor	Grays Harbor County	53027	WA	
14	Island	Island	Island County	53029	WA	
15	Jefferson	Jefferson	Jefferson County	53031	WA	
16	King	King	King County	53033	WA	
17	Kitsap	Kitsap	Kitsap County	53035	WA	
18	Kittitas	Kittitas	Kittitas County	53037	WA	
19	Klickitat	Klickitat	Klickitat County	53039	WA	
20	Lewis	Lewis	Lewis County	53041	WA	
21	Lincoln	Lincoln	Lincoln County	53043	WA	
22	Mason	Mason	Mason County	53045	WA	
23	Okanogan	Okanogan	Okanogan County	53047	WA	
24	Pacific	Pacific	Pacific County	53049	WA	
25	Pend Oreille	Pend Oreille	Pend Oreille County	53051	WA	
26	Pierce	Pierce	Pierce County	53053	WA	
27	San Juan	San Juan	San Juan County	53055	WA	
28	Skagit	Skagit	Skagit County	53057	WA	
29	Skamania	Skamania	Skamania County	53059	WA	
30	Snohomish	Snohomish	Snohomish County	53061	WA	
31	Spokane	Spokane	Spokane County	53063	WA	
32	Stevens	Stevens	Stevens County	53065	WA	
33	Thurston	Thurston	Thurston County	53067	WA	

34	Wahkiakum	Wahkiakum	Wahkiakum County	53069	WA
35	Walla Walla	Walla Walla	Walla Walla County	53071	WA
36	Whatcom	Whatcom	Whatcom County	53073	WA
37	Whitman	Whitman	Whitman County	53075	WA
38	Yakima	Yakima	Yakima County	53077	WA

	state_name	lat	lng	population	District	COUNTY \
0	Washington	46.9834	-118.5606	20353	4	1
1	Washington	46.1918	-117.2030	22285	5	3
2	Washington	46.2398	-119.5112	204551	4	5
3	Washington	47.8692	-120.6190	78508	8	7
4	Washington	48.0493	-123.9280	76727	6	9
5	Washington	45.7792	-122.4825	496494	3	11
6	Washington	46.2975	-117.9078	3969	5	13
7	Washington	46.1932	-122.6810	109457	3	15
8	Washington	47.7361	-119.6918	42622	8	17
9	Washington	48.4703	-118.5166	7198	5	19
10	Washington	46.5347	-118.8990	95313	4	21
11	Washington	46.4316	-117.5452	2278	5	23
12	Washington	47.2057	-119.4518	97874	4	25
13	Washington	47.1503	-123.7735	74737	6	27
14	Washington	48.1630	-122.5481	85938	2	29
15	Washington	47.7487	-123.5960	32590	6	31
16	Washington	47.4902	-121.8052	2240876	7	33
17	Washington	47.6130	-122.6716	273072	6	35
18	Washington	47.1244	-120.6798	44147	8	37
19	Washington	45.8738	-120.7891	22478	3	39
20	Washington	46.5778	-122.3927	81214	3	41
21	Washington	47.5763	-118.4187	10798	5	43
22	Washington	47.3484	-123.1927	64964	6	45
23	Washington	48.5488	-119.7408	41966	4	47
24	Washington	46.5557	-123.7041	22974	6	49
25	Washington	48.5323	-117.2740	13302	5	51
26	Washington	47.0241	-122.1046	910225	10	53
27	Washington	48.5782	-122.9650	17631	2	55
28	Washington	48.4794	-121.7302	128228	2	57
29	Washington	46.0230	-121.9147	11973	3	59
30	Washington	48.0475	-121.6975	820024	1	61
31	Washington	47.6207	-117.4040	531477	5	63
32	Washington	48.3991	-117.8552	46057	5	65
33	Washington	46.9258	-122.8332	290642	10	67
34	Washington	46.2918	-123.4244	4373	3	69
35	Washington	46.2298	-118.4784	62168	5	71
36	Washington	48.8259	-121.7199	224533	1	73
37	Washington	46.9012	-117.5230	48197	5	75
38	Washington	46.4571	-120.7385	255151	4	77

	CTYNAME	TOT_POP	WHITE_POP
0	Adams County	165642	145704
1	Asotin County	179178	165888
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4	Clallam County	621528	537626
5	Clark County	4075954	3474526
6	Columbia County	31884	28776
7	Cowlitz County	890726	806168
8	Douglas County	347996	320036
9	Ferry County	58178	44344
10	Franklin County	781386	699244
11	Garfield County	18606	17062
12	Grant County	800596	730156
13	Grays Harbor County	610632	529248
14	Island County	696038	591440
15	Jefferson County	266376	242286
16	King County	18127176	11714772
17	Kitsap County	2211342	1814044
18	Kittitas County	357690	327504
19	Klickitat County	183998	170452
20	Lewis County	669306	613284
21	Lincoln County	89368	83150
22	Mason County	534292	465360
23	Okanogan County	340224	278120
24	Pacific County	189880	170762
25	Pend Oreille County	109990	99738
26	Pierce County	7398480	5417388
27	San Juan County	145786	136596
28	Skagit County	1043022	939068
29	Skamania County	97466	86544
30	Snohomish County	6667864	5015430
31	Spokane County	4351290	3850124
32	Stevens County	377638	337208
33	Thurston County	2375242	1919370
34	Wahkiakum County	36258	33076
35	Walla Walla County	498506	454124
36	Whatcom County	1823336	1565160
37	Whitman County	373264	312788
38	Yakima County	2054138	1779572

```
[16]: del counties_df['county']
counties_df=counties_df.reset_index(names='county')
counties_df
```

```
[16]:   county  county_ascii      county_full  county_fips  state_id \
0      0      Adams      Adams County      53001      WA
```

1	1	Asotin	Asotin County	53003	WA
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6	6	Columbia	Columbia County	53013	WA
7	7	Cowlitz	Cowlitz County	53015	WA
8	8	Douglas	Douglas County	53017	WA
9	9	Ferry	Ferry County	53019	WA
10	10	Franklin	Franklin County	53021	WA
11	11	Garfield	Garfield County	53023	WA
12	12	Grant	Grant County	53025	WA
13	13	Grays Harbor	Grays Harbor County	53027	WA
14	14	Island	Island County	53029	WA
15	15	Jefferson	Jefferson County	53031	WA
16	16	King	King County	53033	WA
17	17	Kitsap	Kitsap County	53035	WA
18	18	Kittitas	Kittitas County	53037	WA
19	19	Klickitat	Klickitat County	53039	WA
20	20	Lewis	Lewis County	53041	WA
21	21	Lincoln	Lincoln County	53043	WA
22	22	Mason	Mason County	53045	WA
23	23	Okanogan	Okanogan County	53047	WA
24	24	Pacific	Pacific County	53049	WA
25	25	Pend Oreille	Pend Oreille County	53051	WA
26	26	Pierce	Pierce County	53053	WA
27	27	San Juan	San Juan County	53055	WA
28	28	Skagit	Skagit County	53057	WA
29	29	Skamania	Skamania County	53059	WA
30	30	Snohomish	Snohomish County	53061	WA
31	31	Spokane	Spokane County	53063	WA
32	32	Stevens	Stevens County	53065	WA
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34	34	Wahkiakum	Wahkiakum County	53069	WA
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38	38	Yakima	Yakima County	53077	WA

	state_name	lat	lng	population	District	COUNTY	\
0	Washington	46.9834	-118.5606	20353	4	1	
1	Washington	46.1918	-117.2030	22285	5	3	
2	Washington	46.2398	-119.5112	204551	4	5	
3	Washington	47.8692	-120.6190	78508	8	7	
4	Washington	48.0493	-123.9280	76727	6	9	
5	Washington	45.7792	-122.4825	496494	3	11	
6	Washington	46.2975	-117.9078	3969	5	13	

7	Washington	46.1932	-122.6810	109457	3	15
8	Washington	47.7361	-119.6918	42622	8	17
9	Washington	48.4703	-118.5166	7198	5	19
10	Washington	46.5347	-118.8990	95313	4	21
11	Washington	46.4316	-117.5452	2278	5	23
12	Washington	47.2057	-119.4518	97874	4	25
13	Washington	47.1503	-123.7735	74737	6	27
14	Washington	48.1630	-122.5481	85938	2	29
15	Washington	47.7487	-123.5960	32590	6	31
16	Washington	47.4902	-121.8052	2240876	7	33
17	Washington	47.6130	-122.6716	273072	6	35
18	Washington	47.1244	-120.6798	44147	8	37
19	Washington	45.8738	-120.7891	22478	3	39
20	Washington	46.5778	-122.3927	81214	3	41
21	Washington	47.5763	-118.4187	10798	5	43
22	Washington	47.3484	-123.1927	64964	6	45
23	Washington	48.5488	-119.7408	41966	4	47
24	Washington	46.5557	-123.7041	22974	6	49
25	Washington	48.5323	-117.2740	13302	5	51
26	Washington	47.0241	-122.1046	910225	10	53
27	Washington	48.5782	-122.9650	17631	2	55
28	Washington	48.4794	-121.7302	128228	2	57
29	Washington	46.0230	-121.9147	11973	3	59
30	Washington	48.0475	-121.6975	820024	1	61
31	Washington	47.6207	-117.4040	531477	5	63
32	Washington	48.3991	-117.8552	46057	5	65
33	Washington	46.9258	-122.8332	290642	10	67
34	Washington	46.2918	-123.4244	4373	3	69
35	Washington	46.2298	-118.4784	62168	5	71
36	Washington	48.8259	-121.7199	224533	1	73
37	Washington	46.9012	-117.5230	48197	5	75
38	Washington	46.4571	-120.7385	255151	4	77

	CTYNAME	TOT_POP	WHITE_POP
0	Adams County	165642	145704
1	Asotin County	179178	165888
2	Benton County	1675328	1501572
3	Chelan County	636014	591962
4	Clallam County	621528	537626
5	Clark County	4075954	3474526
6	Columbia County	31884	28776
7	Cowlitz County	890726	806168
8	Douglas County	347996	320036
9	Ferry County	58178	44344
10	Franklin County	781386	699244
11	Garfield County	18606	17062
12	Grant County	800596	730156

13	Grays Harbor County	610632	529248
14	Island County	696038	591440
15	Jefferson County	266376	242286
16	King County	18127176	11714772
17	Kitsap County	2211342	1814044
18	Kittitas County	357690	327504
19	Klickitat County	183998	170452
20	Lewis County	669306	613284
21	Lincoln County	89368	83150
22	Mason County	534292	465360
23	Okanogan County	340224	278120
24	Pacific County	189880	170762
25	Pend Oreille County	109990	99738
26	Pierce County	7398480	5417388
27	San Juan County	145786	136596
28	Skagit County	1043022	939068
29	Skamania County	97466	86544
30	Snohomish County	6667864	5015430
31	Spokane County	4351290	3850124
32	Stevens County	377638	337208
33	Thurston County	2375242	1919370
34	Wahkiakum County	36258	33076
35	Walla Walla County	498506	454124
36	Whatcom County	1823336	1565160
37	Whitman County	373264	312788
38	Yakima County	2054138	1779572

```
[17]: # Washington has 10 districts
max_district = 10
counties_df['TOT_POP'] = counties_df['TOT_POP'].astype("int")
counties_df['WHITE_POP'] = counties_df['WHITE_POP'].astype("int")
counties_df['lat'] = counties_df['lat'].astype("float")
counties_df['lng'] = counties_df['lng'].astype("float")

max_district = 10
max_population = (counties_df['population'].sum() / max_district) * 1.5
statewide_white_percentage = counties_df['WHITE_POP'].sum() / \
    counties_df['TOT_POP'].sum()

counties_lat_Dic = dict(zip(counties_df.county, counties_df.lat))
counties_Long_Dic = dict(zip(counties_df.county, counties_df.lng))
counties_Pop_Dic = dict(zip(counties_df.county, counties_df.TOT_POP))
counties_WhitePop_Dic = dict(zip(counties_df.county, counties_df.WHITE_POP))
```

```
[18]: county_adjacency = {}
with open("data/county_adjacency.txt", 'r', encoding='ISO-8859-1') as file:
    lines = file.readlines()
```

```

for line in lines:
    parts = line.strip().split('\t')
    if len(parts) < 4:
        continue
    county_fips = parts[1]
    if county_fips.startswith('53'):
        county_name = parts[0].replace('\"', '')
        adjacent_county_fips = parts[3]
        adjacent_county_name = parts[2].replace('\"', '')
        if county_name not in county_adjacency:
            county_adjacency[county_name] = []
        if adjacent_county_fips.startswith('53'):
            county_adjacency[county_name].append(adjacent_county_name)

sorted_counties = sorted(county_adjacency.keys())
adjacency_matrix = pd.DataFrame(0, index=sorted_counties,
    ↪ columns=sorted_counties, dtype=int)
for county, neighbors in county_adjacency.items():
    for neighbor in neighbors:
        adjacency_matrix.at[county, neighbor] = 1
        adjacency_matrix.at[neighbor, county] = 1

county_index_to_name_map = counties_df['county'].to_dict()

index_to_county_map = {index: county for index, county in
    ↪ enumerate(counties_df['county'])}

```

```

[19]: adjacency_matrix=adjacency_matrix.sort_index().reset_index(drop=True)
adjacency_matrix.columns = counties_df['county'].to_list()
adjacency_matrix

```

```

[19]:
   0  1  2  3  4  5  6  7  8  9  ...  29  30  31  32  33  34  35  \
0   1  0  0  0  0  0  0  0  0  0  ...  0  0  0  0  0  0  0
1   0  0  0  0  0  0  0  0  0  0  ...  0  0  0  0  0  0  0
2   0  0  0  0  0  0  0  0  0  0  ...  0  0  0  0  0  0  0
3   0  0  0  1  0  0  0  0  1  0  ...  0  1  0  0  0  0  0
4   0  0  0  0  1  0  0  0  0  0  ...  0  0  0  0  0  0  0
5   0  0  0  0  0  0  0  0  0  0  ...  0  0  0  0  0  0  0
6   0  0  0  0  0  0  0  0  0  0  ...  0  0  0  0  0  0  0
7   0  0  0  0  0  0  0  0  0  0  ...  0  0  0  0  0  0  0
8   0  0  0  1  0  0  0  0  0  0  ...  0  0  0  0  0  0  0
9   0  0  0  0  0  0  0  0  0  1  ...  0  0  0  1  0  0  0
10  1  0  0  0  0  0  0  0  0  0  ...  0  0  0  0  0  0  0
11  0  0  0  0  0  0  0  0  0  0  ...  0  0  0  0  0  0  0

```

12	1	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	1	0	0
14	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
15	0	0	0	0	1	0	0	0	0	0	...	0	0	0	0	0	0	0
16	0	0	0	1	0	0	0	0	0	0	...	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
18	0	0	0	1	0	0	0	0	0	0	...	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	1	0	0	...	0	0	0	0	0	0	0
21	1	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
23	0	0	0	1	0	0	0	0	0	0	...	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
27	0	0	0	0	1	0	0	0	0	0	...	0	0	0	0	0	0	0
28	0	0	0	1	0	0	0	0	0	0	...	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
30	0	0	0	1	0	0	0	0	0	0	...	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	1	...	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0
38	0	0	1	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0

	36	37	38
0	0	0	0
1	0	0	0
2	0	0	1
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0

```

18  0  0  0
19  0  0  0
20  0  0  0
21  0  0  0
22  0  0  0
23  1  0  0
24  0  0  0
25  0  0  0
26  0  0  0
27  0  0  0
28  0  0  0
29  0  0  0
30  0  0  0
31  0  0  0
32  0  0  0
33  0  0  0
34  0  0  0
35  0  0  0
36  0  0  0
37  0  0  0
38  0  0  0

```

[39 rows x 39 columns]

```

[20]: from pyscipopt import Model, quicksum
      from itertools import chain, combinations
      import statistics as stats

      def compactness(district):
          lat_list = [counties_lat_Dic[county] for county in district]
          long_list = [counties_Long_Dic[county] for county in district]

          lat_sd = stats.stdev(lat_list)
          long_sd = stats.stdev(long_list)

          return lat_sd + long_sd

      def total_pop(district):
          pop_list = [counties_Pop_Dic.get(county, 0) for county in district]
          return sum(pop_list)

      def white_pop_percentage(district):
          white_pop_list = [counties_WhitePop_Dic.get(county, 0) for county in
↪district]

```

```

total_pop_list = [counties_Pop_Dic.get(county, 0) for county in district]
white_pop = sum(white_pop_list)
total_pop = sum(total_pop_list)
return (white_pop / total_pop) if total_pop > 0 else 0

min_len = 2
max_len = 5
counties = counties_df['county'].tolist()
possible_districts = list(chain.from_iterable(combinations(counties, i) for i
    in range(min_len, max_len + 1)))

redistrict_model = Model("Redistricting Model")

x = {}
for district in possible_districts:
    x[district] = redistrict_model.addVar(vtype="B", name="district_{}".
    format(district))

objective_terms = [
    compactness(district) * x[district] for district in possible_districts
] + [
    abs(white_pop_percentage(district) - statewide_white_percentage) *
    x[district] for district in possible_districts
]
redistrict_model.setObjective(quicksum(objective_terms), "minimize")

redistrict_model.addCons(quicksum(x[district] for district in
    possible_districts) == max_district, "Maximum_number_of_districts")

for district in possible_districts:
    for county1 in district:
        for county2 in district:
            if county1 != county2:
                if adjacency_matrix.at[county1, county2] == 0:
                    redistrict_model.addCons(x[district] == 0)

redistrict_model.optimize()

status = redistrict_model.getStatus()
if status == "optimal":
    print("Optimal solution found!")
    for district in possible_districts:
        if redistrict_model.getVal(x[district]) > 0:
            print(f"District {district}: {redistrict_model.
    getVal(x[district])}")
else:
    print("No optimal solution found. Status:", status)

```



```

presolving:
Optimal solution found!
District (0, 10): 1.0
District (0, 21): 1.0
District (3, 18): 1.0
District (4, 15): 1.0
District (7, 20): 1.0
District (9, 32): 1.0
District (13, 22): 1.0
District (13, 33): 1.0
District (14, 17): 1.0
District (16, 26): 1.0
(round 1, fast)      667869 del vars, 12236456 del conss, 0 add conss, 667869
chg bounds, 0 chg sides, 0 chg coeffs, 0 upgd conss, 0 impls, 0 clqs
  (30.9s) running MILP presolver
  (31.1s) MILP presolver found nothing
  (31.1s) probing cycle finished: starting next cycle
  (31.1s) symmetry computation started: requiring (bin +, int -, cont +),
(fixed: bin -, int +, cont -)
  (31.1s) no symmetry present
presolving (2 rounds: 2 fast, 1 medium, 1 exhaustive):
  667869 deleted vars, 12236456 deleted constraints, 0 added constraints, 667869
tightened bounds, 0 added holes, 0 changed sides, 0 changed coefficients
  0 implications, 0 cliques
presolved problem has 19 variables (19 bin, 0 int, 0 impl, 0 cont) and 1
constraints
  1 constraints of type <linear>
Presolving Time: 15.41

```

time	node	left	LP iter	LP it/n	mem/heur	mdpt	vars	cons	rows	cuts
sepa	confs	strbr	dualbound	primalbound	gap	compl.				
p31.2s	1	0	0	-	locks	0	19	1	1	0
0	0	0	0.000000e+00	9.109755e+00	Inf	unknown				
*31.2s	1	0	1	-	LP	0	19	1	1	0
0	0	0	6.498894e+00	6.498894e+00	0.00%	unknown				
31.2s	1	0	1	-	7696M	0	19	1	1	0
0	0	0	6.498894e+00	6.498894e+00	0.00%	unknown				

```

SCIP Status      : problem is solved [optimal solution found]
Solving Time (sec) : 31.17
Solving Nodes    : 1
Primal Bound     : +6.49889435550852e+00 (2 solutions)
Dual Bound      : +6.49889435550852e+00
Gap              : 0.00 %

```

```

[21]: def check_no_change(orig, opt):
      if opt == 0:

```

```

        return orig
    else:
        return opt

if redistribute_model.getStatus() == 'optimal':
    chosen_districts = [district for district in possible_districts if
↳redistribute_model.getVal(x[district]) > 0.5]
    county_to_district_map = {}
    district_number = 1
    for district in chosen_districts:
        for county in district:

            county_to_district_map[county] = district_number
            district_number += 1

    counties_df['Optimized_District'] = counties_df['county'].apply(lambda c:
↳county_to_district_map.get(c, 0))

    counties_df['Optimized_District'] = counties_df.apply(lambda x:
↳check_no_change(x['District'], x['Optimized_District']), axis=1)

else:
    print("No optimal solution found. Status:", redistribute_model.getStatus())

counties_df['Percent_White']=counties_df['WHITE_POP']/counties_df['TOT_POP']
counties_df.head()

```

```

[21]:
   county county_ascii county_full county_fips state_id state_name \
0      0      Adams Adams County      53001      WA Washington
1      1      Asotin Asotin County      53003      WA Washington
2      2      Benton Benton County      53005      WA Washington
3      3      Chelan Chelan County      53007      WA Washington
4      4      Clallam Clallam County      53009      WA Washington

   lat lng population District COUNTY CTYNAME TOT_POP \
0  46.9834 -118.5606      20353         4      1 Adams County  165642
1  46.1918 -117.2030      22285         5      3 Asotin County  179178
2  46.2398 -119.5112     204551         4      5 Benton County 1675328
3  47.8692 -120.6190      78508         8      7 Chelan County  636014
4  48.0493 -123.9280      76727         6      9 Clallam County  621528

   WHITE_POP Optimized_District Percent_White
0      145704                2      0.879632
1      165888                5      0.925828
2     1501572                4      0.896285
3      591962                3      0.930737

```

4 537626 4 0.865007

```
[22]: import geopandas as gpd

geojson_path = 'data/washington-state-counties_.geojson'
geojson_gdf = gpd.read_file(geojson_path)
counties_df['county_full'] = counties_df['county_full'].str.title()
merged_gdf = geojson_gdf.merge(counties_df, left_on='NAME',
    ↪right_on='county_ascii', how='left')
merged_gdf[['county', 'NAME', 'District', 'Optimized_District',
    ↪'Percent_White', 'geometry']]
```

```
[22]:
```

	county	NAME	District	Optimized_District	Percent_White	\
0	2	Benton	4	4	0.896285	
1	4	Clallam	6	4	0.865007	
2	5	Clark	3	3	0.852445	
3	7	Cowlitz	3	5	0.905068	
4	12	Grant	4	4	0.912016	
5	15	Jefferson	6	4	0.909564	
6	18	Kittitas	8	3	0.915608	
7	22	Mason	6	7	0.870984	
8	30	Snohomish	1	1	0.752179	
9	21	Lincoln	5	2	0.930423	
10	23	Okanogan	4	4	0.817461	
11	24	Pacific	6	6	0.899315	
12	28	Skagit	2	2	0.900334	
13	38	Yakima	4	4	0.866335	
14	3	Chelan	8	3	0.930737	
15	9	Ferry	5	6	0.762213	
16	14	Island	2	9	0.849724	
17	17	Kitsap	6	9	0.820336	
18	20	Lewis	3	5	0.916298	
19	26	Pierce	10	10	0.732230	
20	32	Stevens	5	6	0.892940	
21	36	Whatcom	1	1	0.858405	
22	10	Franklin	4	1	0.894877	
23	37	Whitman	5	5	0.837981	
24	8	Douglas	8	8	0.919654	
25	27	San Juan	2	2	0.936962	
26	33	Thurston	10	8	0.808073	
27	0	Adams	4	2	0.879632	
28	13	Grays Harbor	6	8	0.866722	
29	16	King	7	10	0.646255	
30	19	Klickitat	3	3	0.926380	
31	35	Walla Walla	5	5	0.910970	
32	29	Skamania	3	3	0.887940	
33	34	Wahkiakum	3	3	0.912240	

34	1	Asotin	5	5	0.925828
35	6	Columbia	5	5	0.902522
36	25	Pend Oreille	5	5	0.906792
37	31	Spokane	5	5	0.884824
38	11	Garfield	5	5	0.917016

```

                                geometry
0  MULTIPOLYGON Z (((-119.87615 46.56757 0.00000,...
1  MULTIPOLYGON Z (((-124.60221 48.38693 0.00000,...
2  MULTIPOLYGON Z (((-122.79596 45.82502 0.00000,...
3  MULTIPOLYGON Z (((-123.21784 46.38513 0.00000,...
4  MULTIPOLYGON Z (((-120.04227 47.07625 0.00000,...
5  MULTIPOLYGON Z (((-122.94347 48.12291 0.00000,...
6  MULTIPOLYGON Z (((-121.46618 47.36802 0.00000,...
7  MULTIPOLYGON Z (((-123.50603 47.34404 0.00000,...
8  MULTIPOLYGON Z (((-122.33164 48.02056 0.00000,...
9  MULTIPOLYGON Z (((-118.97928 47.36417 0.00000,...
10 MULTIPOLYGON Z (((-120.88572 48.97483 0.00000,...
11 MULTIPOLYGON Z (((-124.09767 46.79409 0.00000,...
12 MULTIPOLYGON Z (((-122.53768 48.36366 0.00000,...
13 MULTIPOLYGON Z (((-121.52356 46.38822 0.00000,...
14 MULTIPOLYGON Z (((-121.18071 47.89873 0.00000,...
15 MULTIPOLYGON Z (((-118.86967 48.65360 0.00000,...
16 MULTIPOLYGON Z (((-122.53892 48.20968 0.00000,...
17 MULTIPOLYGON Z (((-122.50492 47.54653 0.00000,...
18 MULTIPOLYGON Z (((-123.37171 46.74263 0.00000,...
19 MULTIPOLYGON Z (((-122.64064 47.14941 0.00000,...
20 MULTIPOLYGON Z (((-118.40241 48.02638 0.00000,...
21 MULTIPOLYGON Z (((-122.59335 48.65142 0.00000,...
22 MULTIPOLYGON Z (((-119.45792 46.67442 0.00000,...
23 MULTIPOLYGON Z (((-118.24912 46.73414 0.00000,...
24 MULTIPOLYGON Z (((-120.31778 47.46275 0.00000,...
25 MULTIPOLYGON Z (((-122.76657 48.70780 0.00000,...
26 MULTIPOLYGON Z (((-123.20207 47.08490 0.00000,...
27 MULTIPOLYGON Z (((-119.36912 46.79559 0.00000,...
28 MULTIPOLYGON Z (((-123.88453 46.96579 0.00000,...
29 MULTIPOLYGON Z (((-122.43694 47.66172 0.00000,...
30 MULTIPOLYGON Z (((-121.61274 45.89886 0.00000,...
31 MULTIPOLYGON Z (((-119.03992 46.19626 0.00000,...
32 MULTIPOLYGON Z (((-122.25008 45.82261 0.00000,...
33 MULTIPOLYGON Z (((-123.72606 46.38563 0.00000,...
34 MULTIPOLYGON Z (((-117.48013 45.99787 0.00000,...
35 MULTIPOLYGON Z (((-118.24264 46.55975 0.00000,...
36 MULTIPOLYGON Z (((-117.62951 48.74268 0.00000,...
37 MULTIPOLYGON Z (((-117.82316 47.37718 0.00000,...
38 MULTIPOLYGON Z (((-117.86194 46.56007 0.00000,...

```

```
[25]: import matplotlib.pyplot as plt
from matplotlib.colors import ListedColormap
from matplotlib.patches import Patch

categorical_colors = ListedColormap(['#1f77b4', '#ff7f0e', '#2ca02c',
    ↪ '#d62728', '#9467bd', '#8c564b', '#e377c2', '#7f7f7f'])

legend_handles = [Patch(facecolor=categorical_colors.colors[i],
    ↪ label=f'District {i+1}') for i in range(8)]
fig, ax = plt.subplots(1, 3, figsize=(35, 25))

geojson_gdf.plot(ax=ax[0], color='white', edgecolor='black')
merged_gdf.plot(ax=ax[0], column='District', legend=True, legend_kwds={'shrink':
    ↪ 0.3})
ax[0].set_title('Original Districts')
ax[0].set_axis_off()

geojson_gdf.plot(ax=ax[1], color='white', edgecolor='black')
merged_gdf.plot(ax=ax[1], column='Percent_White', cmap='viridis', legend=True,
    ↪ legend_kwds={'shrink': 0.3})
ax[1].set_title('Percent White')
ax[1].set_axis_off()

geojson_gdf.plot(ax=ax[2], color='white', edgecolor='black')
merged_gdf.plot(ax=ax[2], column='Optimized_District', legend=True,
    ↪ legend_kwds={'shrink': 0.3})
ax[2].set_title('Optimized Districts')
ax[2].set_axis_off()

plt.show()
```

