Final Notebook

March 14, 2022

1 Final Notebook

In previous notebooks, we have gathered general information about the Gauteng region and its community members, as well as information about social attitudes and BRT use. In this final notebook, I create some of the final outputs we need for our project such as: - interactive maps of the percentage of survey respondents who identify as African with the BRT lines overlayed - created tables to supplement some of our interactive maps - interactive maps of BRT use with the BRT lines overlayed - identified the wards in which BRT use is the highest (over 40%) which we then used to examine social attitudes in these wards - identified and isolated the wards through which the BRT passes and examined changes in social attitudes in those wards between 2011 and 2017

These outputs help us tie our previous explorations together.

1.1 Import necessary libraries

[1]:

```
import pandas as pd

import geopandas as gpd

import contextily as ctx

import matplotlib.pyplot as plt

import plotly.express as px
```

```
/opt/conda/lib/python3.9/site-packages/geopandas/_compat.py:106: UserWarning:
The Shapely GEOS version (3.9.1-CAPI-1.14.2) is incompatible with the GEOS
version PyGEOS was compiled with (3.10.1-CAPI-1.16.0). Conversions between both
will be slow.
  warnings.warn(
```

1.2 Import data

1.2.1 GCRO Quality of Life Survey Data

We had previously trimmed the GCRO data, eliminating all columns except those we would consistently use, and merged it with the respective ward geospatial data in order to avoid conducting a merge in every new notebook

```
[2]: gdf_2011 = gpd.read_file('data_2011_clean')
```

```
[3]: gdf_2017 = gpd.read_file('data_2017_clean')
```

1.2.2 BRT Data

We will be overlaying the BRT lines (provided by the GCRO) on our choropleth maps and creating an interactive map of the BRT stations. I hand coded the BRT stations using geojson.io and will import them here as well for use in our final presentation

```
[4]: BRT_line = gpd.read_file('Gauteng_BRT_lines.zip', encoding="utf-8")
```

```
[5]: BRT_stations = gpd.read_file('BRT_stations2.geojson')
```

1.3 *Brief* Data Exploration

I just want to ensure that all the necessary information is present in the data

```
[6]: gdf_2011.head(5)
```

```
[6]:
     WardID LocalMunicipalityName DistrictMunicipalityName  A1_Pop_Group  \
0  74803012        Rand West City                West Rand           1.0
1  74803012        Rand West City                West Rand           1.0
2  74803012        Rand West City                West Rand           1.0
3  74803012        Rand West City                West Rand           1.0
4  74803012        Rand West City                West Rand           1.0

  A1_Pop_Group_recode  Q4_5 Train_Frequent_Trip_Transp  \
0             African                              NaN
1             African                              NaN
2             African                              NaN
3             African                              NaN
4             African                              1.0

   Q4_5 BRT_Frequent_Trip_Transp  A_4_8_Walking_proxim_pub_transp  \
0                            NaN                              1.0
1                            NaN                              1.0
2                            NaN                              1.0
3                            NaN                              1.0
4                            NaN                              3.0

  A_4_8_Walking_proxim_pub_transp_recode  A_6_31_BW_trust  \
0                  Up to 10 minutes walk              NaN
1                  Up to 10 minutes walk              1.0
2                  Up to 10 minutes walk              2.0
3                  Up to 10 minutes walk              1.0
4             From 21 to 30 minutes walk              1.0
```

```
  A_6_31_BW_trust_recode  A_6_36_foreigners A_6_36_foreigners_recode  African  \
0                   None                3.0             Third person       40
1        Strongly Agree                 1.0             First person       40
2                  Agree                1.0             First person       40
3        Strongly Agree                 1.0             First person       40
4        Strongly Agree                 1.0             First person       40

   Percent African  White  Percent White  \
0            100.0      0            0.0
1            100.0      0            0.0
2            100.0      0            0.0
3            100.0      0            0.0
4            100.0      0            0.0

                                            geometry
0  POLYGON ((27.73847 -26.28225, 27.72304 -26.289…
1  POLYGON ((27.73847 -26.28225, 27.72304 -26.289…
2  POLYGON ((27.73847 -26.28225, 27.72304 -26.289…
3  POLYGON ((27.73847 -26.28225, 27.72304 -26.289…
4  POLYGON ((27.73847 -26.28225, 27.72304 -26.289…
```

[7]:
```
gdf_2017.head(5)
```

[7]:
```
     WardID LocalMunicipalityName DistrictMunicipalityName A1_Pop_group  \
0  79700060            Ekurhuleni               Ekurhuleni      African
1  79700060            Ekurhuleni               Ekurhuleni      African
2  79700060            Ekurhuleni               Ekurhuleni      African
3  79700060            Ekurhuleni               Ekurhuleni      African
4  79700060            Ekurhuleni               Ekurhuleni      African

  Q5_06_8_train Q5_06_10_BRT_TRT Q5_11_BRT_Freq Q5_18_Walk_prox_public_transp  \
0            No               No          Never              Up to 10 minutes
1            No               No          Never         From 11 to 20 minutes
2            No               No          Never              Up to 10 minutes
3            No               No          Never              Up to 10 minutes
4            No               No          Never         From 11 to 20 minutes

              Q9_10_BW_trust  \
0              Strongly agree
1                       Agree
2                    Disagree
3  Neither agree nor disagree
4                       Agree

                        Q9_12_foreigners_scenario  African  \
0   Gauteng is for South Africans, foreigners sho…       54
```

```
1   Foreigners are alright, but they must have le…       54
2   Gauteng is for South Africans, foreigners sho…       54
3   We have a lot in common with most of the fore…       54
4   Foreigners are alright, but they must have le…       54

   Percent African  White  Percent White  \
0            100.0      0            0.0
1            100.0      0            0.0
2            100.0      0            0.0
3            100.0      0            0.0
4            100.0      0            0.0

                                                geometry
0  POLYGON ((28.16493 -26.35885, 28.16632 -26.358…
1  POLYGON ((28.16493 -26.35885, 28.16632 -26.358…
2  POLYGON ((28.16493 -26.35885, 28.16632 -26.358…
3  POLYGON ((28.16493 -26.35885, 28.16632 -26.358…
4  POLYGON ((28.16493 -26.35885, 28.16632 -26.358…
```

For our analysis, we look at the percentage of respondents who identify as African in each ward. To avoid creating the same dataframe in each notebook, when I cleaned the data, I saved the number of African and White respondents in each ward along with the corresponding ward percentage. However, in order to create an interactive choropleth map in Plotly, we need the proportion rather than the percent, as the code multiplies these values by 100. I will add another column with this data to the 2011 and 2017 data

1.4 Interactive Choropleth Maps

1.4.1 2011

Population Groups In order to get the proportion of Africans in each ward, I will use the crosstab command which allows me to see the number of respondents in each population group for each ward.

[8]:

```
pop_group_11 = pd.crosstab(index=gdf_2011['WardID'],
                        columns=gdf_2011['A1_Pop_Group_recode'],
                                                 margins=True,
                       margins_name='Total Number')


pop_group_11
```

[8]:

```
A1_Pop_Group_recode  African  Asian/Indian  Coloured  White  Total Number
WardID
74201001                   3             1         1     16            21
74201002                  27             0         0      0            27
74201003                  13             0         1      8            22
74201004                  11             0         0     16            27
74201005                   7             2         1     16            26
```

```
…                      …           …       …    …           …
79900102                  39              0         0      1            40
79900103                  67              0         0      1            68
79900104                   3              0         0      1             4
79900105                  36              1         0      1            38
Total Number           13338            491       572   2328         16729

[508 rows x 5 columns]
```

Now that I have the respondent answers listed by ward, I will create normalized data for the African population group by dividing the number of African respondents by the total number of respondents in each ward

[9]:

```
pop_group_11['Percent African Decimal'] = pop_group_11['African']/
 ↪pop_group_11['Total Number']

pop_group_11
```

[9]:

```
A1_Pop_Group_recode  African  Asian/Indian  Coloured  White  Total Number  \
WardID
74201001                   3              1         1     16            21
74201002                  27              0         0      0            27
74201003                  13              0         1      8            22
74201004                  11              0         0     16            27
74201005                   7              2         1     16            26
…                      …           …       …    …           …
79900102                  39              0         0      1            40
79900103                  67              0         0      1            68
79900104                   3              0         0      1             4
79900105                  36              1         0      1            38
Total Number           13338            491       572   2328         16729

A1_Pop_Group_recode  Percent African Decimal
WardID
74201001                            0.142857
74201002                            1.000000
74201003                            0.590909
74201004                            0.407407
74201005                            0.269231
…                                      …
79900102                            0.975000
79900103                            0.985294
79900104                            0.750000
79900105                            0.947368
Total Number                        0.797298

[508 rows x 6 columns]
```

I want to drop the ‘Total Number’ column from this dataframe as to not be included in my final output

```
[10]: pop_group_11 = pop_group_11.drop(['Total Number'])
```

I want to save a dataframe with *just* the newly created column so I will isolate that column

```
[11]: pop_group_11=pop_group_11[['Percent African Decimal']]

      pop_group_11
```

```
[11]: A1_Pop_Group_recode  Percent African Decimal
      WardID
      74201001                            0.142857
      74201002                            1.000000
      74201003                            0.590909
      74201004                            0.407407
      74201005                            0.269231
      …                                      …
      79900101                            0.400000
      79900102                            0.975000
      79900103                            0.985294
      79900104                            0.750000
      79900105                            0.947368

      [507 rows x 1 columns]
```

I want to merge this dataframe with the 2011 geospatial ward data in order to create a choropleth map so first I’ll import the necessary data (the wards in 2011) and then conduct a merge.

```
[12]: wards_2011 = gpd.read_file('MDB_Wards_2011.geojson')
```

```
[13]: pop_group_11_gdf = wards_2011.merge(pop_group_11, on='WardID')

      pop_group_11_gdf
```

```
[13]:       OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
      0          330           GT      Gauteng                 GT485         12
      1         4607           GT      Gauteng                 GT485         12
      2          331           GT      Gauteng                 GT485         13
      3         4608           GT      Gauteng                 GT485         13
      4          354           GT      Gauteng                 GT423          4
      …          …          …          …                 …          …
      1009      7862           GT      Gauteng                   TSH        103
      1010      3586           GT      Gauteng                   TSH        104
      1011      7863           GT      Gauteng                   TSH        104
      1012      3587           GT      Gauteng                   TSH        105
      1013      7864           GT      Gauteng                   TSH        105
```

```
        WardID LocalMunicipalityName DistrictMunicipalityCode  \
0     74803012        Rand West City                     DC48
1     74803012        Rand West City                     DC48
2     74803013        Rand West City                     DC48
3     74803013        Rand West City                     DC48
4     74203004                Lesedi                     DC42
…        …                  …                      …
1009  79900103       City of Tshwane                      TSH
1010  79900104       City of Tshwane                      TSH
1011  79900104       City of Tshwane                      TSH
1012  79900105       City of Tshwane                      TSH
1013  79900105       City of Tshwane                      TSH

     DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
0                   West Rand  2011  6.661918e+06   13537.806926
1                   West Rand  2011  6.661918e+06   13537.806926
2                   West Rand  2011  4.788824e+05    4313.058347
3                   West Rand  2011  4.788824e+05    4313.058347
4                    Sedibeng  2011  9.282691e+05    4710.126049
…                       …   …          …             …
1009          City of Tshwane  2011  6.245816e+07   47894.621520
1010          City of Tshwane  2011  2.630179e+07   23861.425039
1011          City of Tshwane  2011  2.630179e+07   23861.425039
1012          City of Tshwane  2011  1.322401e+09  327991.053295
1013          City of Tshwane  2011  1.322401e+09  327991.053295

                                               geometry  \
0     POLYGON ((27.73847 -26.28225, 27.72304 -26.289…
1     POLYGON ((27.73847 -26.28225, 27.72304 -26.289…
2     POLYGON ((27.71000 -26.28295, 27.70973 -26.283…
3     POLYGON ((27.71000 -26.28295, 27.70973 -26.283…
4     POLYGON ((28.32999 -26.55073, 28.32880 -26.552…
…                                                  …
1009  POLYGON ((28.71646 -25.68544, 28.71673 -25.685…
1010  POLYGON ((28.76233 -25.66340, 28.75908 -25.677…
1011  POLYGON ((28.76233 -25.66340, 28.75908 -25.677…
1012  POLYGON ((29.08001 -25.49463, 29.09137 -25.530…
1013  POLYGON ((29.08001 -25.49463, 29.09137 -25.530…

      Percent African Decimal
0                    1.000000
1                    1.000000
2                    1.000000
3                    1.000000
4                    0.981132
…                       …
```

```
1009                   0.985294
1010                   0.750000
1011                   0.750000
1012                   0.947368
1013                   0.947368

[1014 rows x 14 columns]
```

It looks like the merge was successful!

Wards with the highest and lowest percentage of African respondents Now I want to identify the wards in which African population are highest and lowest

[14]:
```
ward_high_afpop = pop_group_11_gdf[pop_group_11_gdf['Percent African␣
 ↪Decimal']==1.0]
```

[15]:
```
print ('There are ' + str(len(ward_high_afpop)) + ' wards in which the␣
 ↪population of Africans is 100%')
```

```
There are 262 wards in which the population of Africans is 100%
```

We can see that there are over 250 wards in which the population of Africans is 100%. 262 is too long to create a table (I think respondents would be scrolling forever!) So I will create a table with ten values

[16]:
```
highest_percent_afpop_2011 = pop_group_11_gdf.sort_values(by = "Percent African␣
 ↪Decimal", ascending=False).head(10)

highest_percent_afpop_2011
```

[16]:
```
     OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
0         330           GT      Gauteng                 GT485         12
271      7449           GT      Gauteng                   EKU         57
269      7448           GT      Gauteng                   EKU         56
268      3171           GT      Gauteng                   EKU         56
679      7697           GT      Gauteng                   JHB         44
680      3421           GT      Gauteng                   JHB         45
681      7698           GT      Gauteng                   JHB         45
684      3423           GT      Gauteng                   JHB         47
685      7700           GT      Gauteng                   JHB         47
686      3424           GT      Gauteng                   JHB         48

       WardID LocalMunicipalityName DistrictMunicipalityCode  \
0    74803012        Rand West City                     DC48
271  79700057            Ekurhuleni                      EKU
269  79700056            Ekurhuleni                      EKU
268  79700056            Ekurhuleni                      EKU
679  79800044  City of Johannesburg                      JHB
```

```
680  79800045  City of Johannesburg                      JHB
681  79800045  City of Johannesburg                      JHB
684  79800047  City of Johannesburg                      JHB
685  79800047  City of Johannesburg                      JHB
686  79800048  City of Johannesburg                      JHB

    DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
0                  West Rand  2011  6.661918e+06   13537.806926
271               Ekurhuleni  2011  5.490537e+06   16690.678628
269               Ekurhuleni  2011  3.050105e+06    8089.045752
268               Ekurhuleni  2011  3.050105e+06    8089.045752
679     City of Johannesburg  2011  7.720567e+06   15541.446187
680     City of Johannesburg  2011  2.326851e+06    7956.596716
681     City of Johannesburg  2011  2.326851e+06    7956.596716
684     City of Johannesburg  2011  2.891492e+06    9748.138396
685     City of Johannesburg  2011  2.891492e+06    9748.138396
686     City of Johannesburg  2011  3.910968e+06   11637.406476

                                              geometry  \
0    POLYGON ((27.73847 -26.28225, 27.72304 -26.289…
271  POLYGON ((28.10968 -26.35560, 28.11993 -26.360…
269  POLYGON ((28.13349 -26.34377, 28.13549 -26.344…
268  POLYGON ((28.13349 -26.34377, 28.13549 -26.344…
679  POLYGON ((27.86695 -26.18700, 27.86695 -26.187…
680  POLYGON ((27.88383 -26.21438, 27.88383 -26.214…
681  POLYGON ((27.88383 -26.21438, 27.88383 -26.214…
684  POLYGON ((27.87186 -26.21974, 27.87194 -26.220…
685  POLYGON ((27.87186 -26.21974, 27.87194 -26.220…
686  POLYGON ((27.85848 -26.21739, 27.85862 -26.220…

     Percent African Decimal
0                        1.0
271                      1.0
269                      1.0
268                      1.0
679                      1.0
680                      1.0
681                      1.0
684                      1.0
685                      1.0
686                      1.0
```

I want this table to be a supplement to the 2011 choropleth map so I will trim the columns to only the ones I believe will be helpful

[17]:

```
highest_percent_afpop_2011 = highest_percent_afpop_2011[['WardID',␣
↪'LocalMunicipalityName', 'DistrictMunicipalityName', 'Percent African␣
↪Decimal']]

highest_percent_afpop_2011
```

[17]:

```
       WardID LocalMunicipalityName DistrictMunicipalityName  \
0    74803012        Rand West City                West Rand
271  79700057            Ekurhuleni               Ekurhuleni
269  79700056            Ekurhuleni               Ekurhuleni
268  79700056            Ekurhuleni               Ekurhuleni
679  79800044  City of Johannesburg     City of Johannesburg
680  79800045  City of Johannesburg     City of Johannesburg
681  79800045  City of Johannesburg     City of Johannesburg
684  79800047  City of Johannesburg     City of Johannesburg
685  79800047  City of Johannesburg     City of Johannesburg
686  79800048  City of Johannesburg     City of Johannesburg

     Percent African Decimal
0                        1.0
271                      1.0
269                      1.0
268                      1.0
679                      1.0
680                      1.0
681                      1.0
684                      1.0
685                      1.0
686                      1.0
```

While I think the table offers ***some*** useful information, it is important to note that there are over 250 wards in which the percentage of Africans is 100% and I am not sure how Python selects the values represented in the top 10.

I would now like to examine the 2011 wards in which the percentage of Africans is the lowest

[18]:

```
ward_low_afpop_2011 = pop_group_11_gdf[pop_group_11_gdf['Percent African␣
↪Decimal']==0]
```

[19]:

```
print ('There are ' + str(len(ward_low_afpop_2011)) + ' wards in which the␣
↪population of Africans is 0%')
```

```
There are 4 wards in which the population of Africans is 0%
```

I also want to create a table for this information.

[20]:

```
lowest_percent_afpop_2011 = pop_group_11_gdf.sort_values(by = "Percent African␣
↪Decimal", ascending=True).head(4)
```

```
lowest_percent_afpop_2011
```

```
[20]:     OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
998       3580           GT      Gauteng                   TSH         98
999       7857           GT      Gauteng                   TSH         98
910       3536           GT      Gauteng                   TSH         54
911       7813           GT      Gauteng                   TSH         54

       WardID LocalMunicipalityName DistrictMunicipalityCode  \
998  79900098        City of Tshwane                      TSH
999  79900098        City of Tshwane                      TSH
910  79900054        City of Tshwane                      TSH
911  79900054        City of Tshwane                      TSH

    DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
998          City of Tshwane  2011  2.861113e+07   28189.266995
999          City of Tshwane  2011  2.861113e+07   28189.266995
910          City of Tshwane  2011  1.293381e+07   19047.063955
911          City of Tshwane  2011  1.293381e+07   19047.063955

                                              geometry  \
998  POLYGON ((28.16604 -25.66844, 28.16592 -25.669…
999  POLYGON ((28.16604 -25.66844, 28.16592 -25.669…
910  POLYGON ((28.19831 -25.69105, 28.20185 -25.691…
911  POLYGON ((28.19831 -25.69105, 28.20185 -25.691…

     Percent African Decimal
998                      0.0
999                      0.0
910                      0.0
911                      0.0
```

```
[21]: lowest_percent_afpop_2011 = lowest_percent_afpop_2011[['WardID',␣
       ↪'LocalMunicipalityName', 'DistrictMunicipalityName', 'Percent African␣
       ↪Decimal']]

      lowest_percent_afpop_2011
```

```
[21]:      WardID LocalMunicipalityName DistrictMunicipalityName  \
998  79900098        City of Tshwane          City of Tshwane
999  79900098        City of Tshwane          City of Tshwane
910  79900054        City of Tshwane          City of Tshwane
911  79900054        City of Tshwane          City of Tshwane

     Percent African Decimal
998                      0.0
999                      0.0
```

```
910                        0.0
911                        0.0
```

Interestingly, the wards in which African population is 0 are located in Tshwane

Choropleth maps Plotly accepts geojson information, so I will convert my data into geojson to create the choropleth map

[22]:

```
pop_wards_2011 = pop_group_11_gdf.to_crs(epsg=4326) # convert the coordinate reference system to lat/long
pop_wards_2011_json = pop_group_11_gdf.__geo_interface__ #covert to geoJSON
```

The plotly code requires additional library imports so I wll bring those in

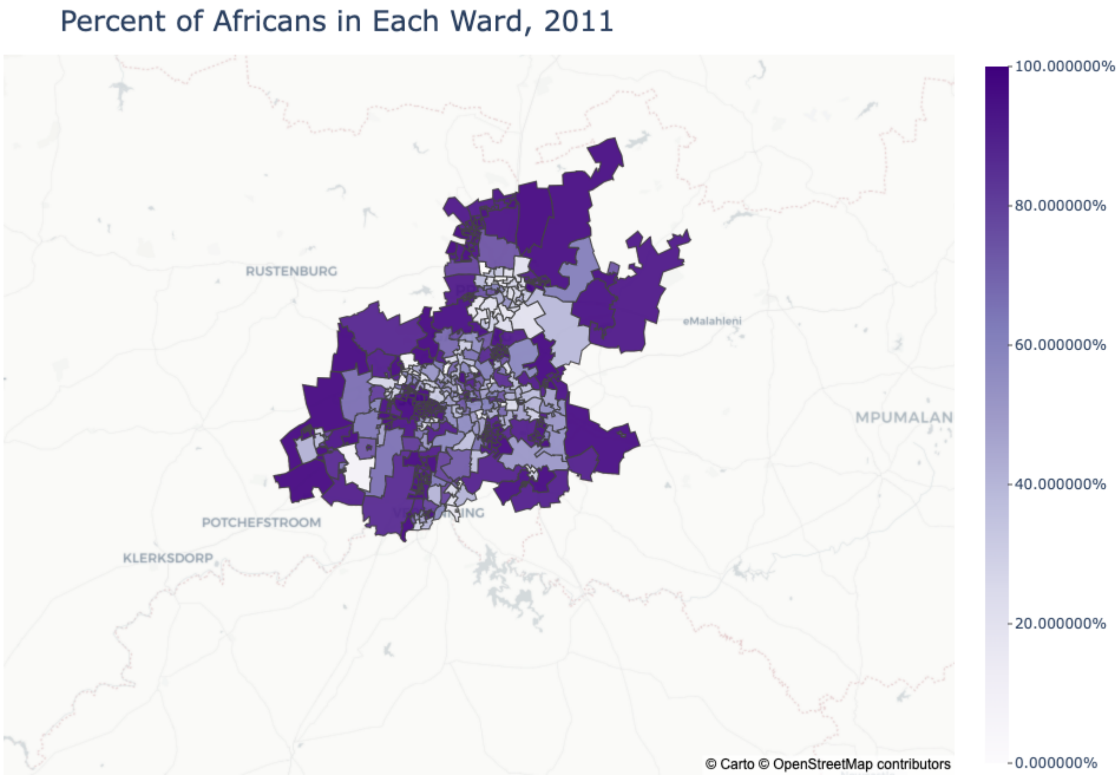
[23]:

```
from mpl_toolkits.axes_grid1 import make_axes_locatable
import plotly.graph_objects as go
```

[24]:

```
zmin = pop_wards_2011['Percent African Decimal'].min() #set the map min and max
zmax = pop_wards_2011['Percent African Decimal'].max()

# Set the data for the map
data = go.Choroplethmapbox(
        geojson = pop_wards_2011_json,
        locations = pop_wards_2011.index,
        z = pop_wards_2011['Percent African Decimal'],
        text = pop_wards_2011.WardID,
        colorbar=dict(thickness=20, ticklen=3, tickformat='%',outlinewidth=0),
        marker_line_width=1, marker_opacity=0.7, colorscale="Purples",
        zmin=zmin, zmax=zmax,
        hovertemplate = "<b>%{text}</b><br>" +
                    "%{z:.1%}<br>" +
                    "<extra></extra>")

# Set the layout for the map
layout = go.Layout(
title = {'text': f"Percent of Africans in Each Ward, 2011",
            'font': {'size':24}},
    mapbox1 = dict(
        domain = {'x': [0, 1],'y': [0, 1]},
        center = dict(lat=-26.270760, lon=28.112268),
        zoom = 7),
    autosize=True,
    height=650,
    margin=dict(l=0, r=0, t=40, b=0))


fig=go.Figure(data=data, layout=layout)
```

```
fig.update_layout(mapbox_style="carto-positron")
fig.show()
#fig.write_html("purple_Africans_ward_2011.html") #I made this code into a␣
↪comment so it wouldn't keep updating the html file
```



This interactive map shows us the percentage of Africans in each ward. Viewers can zoom into each ward and see the Ward ID number along with the percentage of Africans in each ward. This will be incredibly helpful when we need to identify the wards that the BRT lines pass through. In looking at this map, we can also see that the wards on the periphery of the region have some of highest percentages of Africans while those more inland, closer to cities like Johannesburg and Pretoria have lower percentages of Africans

1.4.2 2017

Now that we have the interactive map for 2011, I will create one for 2017 and examine the wards in which the percentage of Africans is highest and lowest

[25]:
```
pop_group_17 = pd.crosstab(index=gdf_2017['WardID'],
                        columns=gdf_2017['A1_Pop_group'],
                                                 margins=True,
                       margins_name='Total Number')


pop_group_17
```

```
[25]: A1_Pop_group  African  Coloured  Indian/Asian  Other  White  Total Number
      WardID
      74201001           11         2             0      0     23            36
      74201002           36         1             0      0      0            37
      74201003           28         2             0      0      4            34
      74201004           24         0             0      0     10            34
      74201005           13         1             0      0     17            31
      …                   …        …            …     …     …               …
      79900104           36         1             0      0      0            37
      79900105           27         1             0      0      3            31
      79900106           37         0             0      1      0            38
      79900107           47         0             0      0      0            47
      Total Number    20964       892           370     85   2578         24889

      [530 rows x 6 columns]
```

Just as I did for the 2011 data, I will create normalized data for the African population group in 2017.

```
[26]: pop_group_17['Percent African Decimal'] = pop_group_17['African']/
       ↪pop_group_17['Total Number']
      pop_group_17['Percent African'] = pop_group_17['African']/pop_group_17['Total␣
       ↪Number']*100

      pop_group_17
```

```
[26]: A1_Pop_group  African  Coloured  Indian/Asian  Other  White  Total Number  \
      WardID
      74201001           11         2             0      0     23            36
      74201002           36         1             0      0      0            37
      74201003           28         2             0      0      4            34
      74201004           24         0             0      0     10            34
      74201005           13         1             0      0     17            31
      …                   …        …            …     …     …               …
      79900104           36         1             0      0      0            37
      79900105           27         1             0      0      3            31
      79900106           37         0             0      1      0            38
      79900107           47         0             0      0      0            47
      Total Number    20964       892           370     85   2578         24889

      A1_Pop_group  Percent African Decimal  Percent African
      WardID
      74201001                     0.305556        30.555556
      74201002                     0.972973        97.297297
      74201003                     0.823529        82.352941
      74201004                     0.705882        70.588235
      74201005                     0.419355        41.935484
```

```
…                                    …          …
79900104                      0.972973  97.297297
79900105                      0.870968  87.096774
79900106                      0.973684  97.368421
79900107                      1.000000 100.000000
Total Number                  0.842300  84.229981

[530 rows x 8 columns]
```

[27]:
```
pop_group_17 = pop_group_17.drop(['Total Number'])
```

I'm going to save the 2017 dataframe with just the newly created column

[28]:
```
pop_group_17=pop_group_17[['Percent African Decimal', 'Percent African']]

pop_group_17
```

[28]:
```
A1_Pop_group  Percent African Decimal  Percent African
WardID
74201001                      0.305556   30.555556
74201002                      0.972973   97.297297
74201003                      0.823529   82.352941
74201004                      0.705882   70.588235
74201005                      0.419355   41.935484
…                                    …          …
79900103                      1.000000 100.000000
79900104                      0.972973  97.297297
79900105                      0.870968  87.096774
79900106                      0.973684  97.368421
79900107                      1.000000 100.000000

[529 rows x 2 columns]
```

I'm going to bring in the 2017 ward geospatial data…

[29]:
```
wards_2017 = gpd.read_file('MDB_Wards_2016.geojson')
```

…and merge it with the dataframe!

[30]:
```
pop_group_17_gdf = wards_2017.merge(pop_group_17, on='WardID')

pop_group_17_gdf
```

[30]:
```
     OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
0        1504           GT      Gauteng                   EKU         60
1        1505           GT      Gauteng                   EKU         61
2        1506           GT      Gauteng                   EKU         62
3        1507           GT      Gauteng                   EKU         63
```

```
4        1508           GT      Gauteng                   EKU          64
..        …          …          …                   …        …
524      4319           GT      Gauteng                   EKU         108
525      4320           GT      Gauteng                   EKU         109
526      4321           GT      Gauteng                   EKU         110
527      4322           GT      Gauteng                   EKU         111
528      4323           GT      Gauteng                   EKU         112

       WardID LocalMunicipalityName DistrictMunicipalityCode  \
0    79700060            Ekurhuleni                      EKU   
1    79700061            Ekurhuleni                      EKU   
2    79700062            Ekurhuleni                      EKU   
3    79700063            Ekurhuleni                      EKU   
4    79700064            Ekurhuleni                      EKU   
..        …                   …                      …   
524  79700108            Ekurhuleni                      EKU   
525  79700109            Ekurhuleni                      EKU   
526  79700110            Ekurhuleni                      EKU   
527  79700111            Ekurhuleni                      EKU   
528  79700112            Ekurhuleni                      EKU   

    DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
0                 Ekurhuleni  2016  3.898607e+06   11472.007890   
1                 Ekurhuleni  2016  2.040419e+07   24911.970404   
2                 Ekurhuleni  2016  5.823267e+07   42030.549363   
3                 Ekurhuleni  2016  3.332302e+06   10253.147328   
4                 Ekurhuleni  2016  1.239711e+07   18521.992239   
..                       …   …           …            …   
524               Ekurhuleni  2016  3.986026e+06   12293.042422   
525               Ekurhuleni  2016  7.126183e+06   17501.893757   
526               Ekurhuleni  2016  8.281005e+06   15886.916039   
527               Ekurhuleni  2016  2.570824e+07   29656.849051   
528               Ekurhuleni  2016  6.723852e+06   14259.004191   

                                              geometry  \
0    POLYGON ((28.16493 -26.35885, 28.16632 -26.358…   
1    POLYGON ((28.13552 -26.40783, 28.13665 -26.408…   
2    POLYGON ((28.24732 -26.38152, 28.25052 -26.386…   
3    POLYGON ((28.16205 -26.37103, 28.16219 -26.371…   
4    POLYGON ((28.22547 -26.35844, 28.22591 -26.358…   
..                                                 …   
524  POLYGON ((28.19092 -26.37677, 28.19174 -26.377…   
525  POLYGON ((28.43689 -26.10593, 28.43703 -26.106…   
526  POLYGON ((28.39511 -26.14457, 28.39570 -26.145…   
527  POLYGON ((28.43582 -26.31314, 28.43659 -26.313…   
528  POLYGON ((28.35914 -26.35703, 28.35931 -26.358…   
     Percent African Decimal  Percent African
0                   1.000000       100.000000
1                   1.000000       100.000000
2                   1.000000       100.000000
3                   1.000000       100.000000
4                   1.000000       100.000000
..                       …                …
524                 1.000000       100.000000
525                 1.000000       100.000000
526                 1.000000       100.000000
527                 0.884615        88.461538
528                 1.000000       100.000000

[529 rows x 15 columns]
```

Population Groups Now I want to find the wards in which African population is highest

```
[31]: ward_high_afpop_2017 = pop_group_17_gdf[pop_group_17_gdf['Percent African␣
       ↪Decimal']==1.0]
```

```
[32]: print ('There are ' + str(len(ward_high_afpop_2017)) + ' wards in which the␣
       ↪population of Africans is 100%')
```

```
There are 235 wards in which the population of Africans is 100%
```

Similar to 2011, in 2017 there are over 200 wards in which the poplulation of Africans is 100%, however there are less wards in which the percentage of Africans is 100%, which could be an indication that the wards are becoming less segregated

```
[33]: highest_percent_afpop_2017 = pop_group_17_gdf.sort_values(by = "Percent African␣
       ↪Decimal", ascending=False).head(10)

      highest_percent_afpop_2017
```

```
[33]:      OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
      0        1504           GT      Gauteng                   EKU         60
      311      3842           GT      Gauteng                 GT481         30
      307      3777           GT      Gauteng                 GT485         35
      305      3775           GT      Gauteng                 GT485         33
      304      3774           GT      Gauteng                 GT485         32
      303      3773           GT      Gauteng                 GT485         31
      301      3771           GT      Gauteng                 GT485         29
      300      3770           GT      Gauteng                 GT485         28
      299      3769           GT      Gauteng                 GT485         27
      294      3764           GT      Gauteng                 GT485         22

             WardID LocalMunicipalityName DistrictMunicipalityCode  \
0    79700060            Ekurhuleni                      EKU
311  74801030           Mogale City                     DC48
307  74205035        Rand West City                     DC48
305  74205033        Rand West City                     DC48
304  74205032        Rand West City                     DC48
303  74205031        Rand West City                     DC48
301  74205029        Rand West City                     DC48
300  74205028        Rand West City                     DC48
299  74205027        Rand West City                     DC48
294  74205022        Rand West City                     DC48

    DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
0                 Ekurhuleni  2016  3.898607e+06   11472.007890
311                West Rand  2016  1.147148e+08   57707.915574
307                West Rand  2016  1.223508e+07   21544.061485
305                West Rand  2016  2.462735e+07   26282.347178
304                West Rand  2016  4.957059e+06   12251.483088
303                West Rand  2016  7.100345e+05    5437.014974
301                West Rand  2016  1.789664e+07   20410.847279
300                West Rand  2016  8.175189e+06   17925.272925
299                West Rand  2016  4.002420e+06    8976.487478
294                West Rand  2016  5.653726e+05    3434.717719

                                              geometry  \
0    POLYGON ((28.16493 -26.35885, 28.16632 -26.358…
311  POLYGON ((27.70048 -26.06088, 27.70052 -26.061…
307  POLYGON ((27.70385 -26.28741, 27.70384 -26.288…
305  POLYGON ((27.72198 -26.23594, 27.72473 -26.238…
304  POLYGON ((27.74465 -26.27949, 27.73847 -26.282…
303  POLYGON ((27.70151 -26.27890, 27.69996 -26.279…
301  POLYGON ((27.70275 -26.27468, 27.70279 -26.275…
300  POLYGON ((27.70131 -26.30890, 27.70163 -26.309…
299  POLYGON ((27.68395 -26.31075, 27.68401 -26.311…
294  POLYGON ((27.70304 -26.22855, 27.70300 -26.228…

     Percent African Decimal  Percent African
0                        1.0            100.0
311                      1.0            100.0
307                      1.0            100.0
305                      1.0            100.0
304                      1.0            100.0
303                      1.0            100.0
301                      1.0            100.0
300                      1.0            100.0
299                      1.0            100.0
294                      1.0            100.0
```

```
[34]: highest_percent_afpop_2017 = highest_percent_afpop_2017[['WardID',␣
       ↪'LocalMunicipalityName', 'DistrictMunicipalityName', 'Percent African␣
       ↪Decimal']]

      highest_percent_afpop_2017
```

```
[34]:        WardID LocalMunicipalityName DistrictMunicipalityName  \
      0    79700060            Ekurhuleni               Ekurhuleni
      311  74801030           Mogale City                West Rand
      307  74205035        Rand West City                West Rand
      305  74205033        Rand West City                West Rand
      304  74205032        Rand West City                West Rand
      303  74205031        Rand West City                West Rand
      301  74205029        Rand West City                West Rand
      300  74205028        Rand West City                West Rand
      299  74205027        Rand West City                West Rand
      294  74205022        Rand West City                West Rand

           Percent African Decimal
      0                        1.0
      311                      1.0
      307                      1.0
      305                      1.0
      304                      1.0
      303                      1.0
      301                      1.0
      300                      1.0
      299                      1.0
      294                      1.0
```

I now want to see the wards in which the percentage of Africans is lowest, to compare it to 2011

```
[35]: ward_low_afpop_2017 = pop_group_17_gdf[pop_group_17_gdf['Percent African␣
       ↪Decimal']==0]
```

```
[36]: print ('There are ' + str(len(ward_low_afpop_2017)) + ' wards in which the␣
       ↪population of Africans is 0%')
```

```
There are 0 wards in which the population of Africans is 0%
```

In 2017, there are 0 wards in which the 100% of the ward identifies as African. I would still like to see the wards in which the percentage of Africans is lowest

```
[37]: lowest_percent_afpop_2017 = pop_group_17_gdf.sort_values(by = "Percent African␣
       ↪Decimal", ascending=True).head(5)

      lowest_percent_afpop_2017
```

```
[37]:      OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
     48       2557           GT      Gauteng                   JHB         18
     112      2621           GT      Gauteng                   JHB         82
     39       2548           GT      Gauteng                   JHB          9
     421      4216           GT      Gauteng                 GT422          2
     485      4280           GT      Gauteng                   EKU         38

            WardID LocalMunicipalityName DistrictMunicipalityCode  \
     48   79800018  City of Johannesburg                      JHB
     112  79800082  City of Johannesburg                      JHB
     39   79800009  City of Johannesburg                      JHB
     421  74202002               Midvaal                     DC42
     485  79700038            Ekurhuleni                      EKU

         DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
     48      City of Johannesburg  2016  7.217249e+06   12634.036845
     112     City of Johannesburg  2016  7.864120e+06   12534.144259
     39      City of Johannesburg  2016  1.614611e+07   27376.989897
     421                 Sedibeng  2016  2.147480e+07   25909.990027
     485               Ekurhuleni  2016  1.512421e+07   20417.571665

                                                   geometry  \
     48   POLYGON ((27.91502 -26.28289, 27.91530 -26.282…
     112  POLYGON ((27.96188 -26.17000, 27.96226 -26.170…
     39   POLYGON ((27.85160 -26.29897, 27.85514 -26.300…
     421  POLYGON ((27.99001 -26.60370, 27.99023 -26.604…
     485  POLYGON ((28.11100 -26.33053, 28.10697 -26.338…

          Percent African Decimal  Percent African
     48                  0.158730        15.873016
     112                 0.196970        19.696970
     39                  0.203390        20.338983
     421                 0.212121        21.212121
     485                 0.222222        22.222222
```

```
[38]: lowest_percent_afpop_2017 = lowest_percent_afpop_2017[['WardID',␣
       ↪'LocalMunicipalityName', 'DistrictMunicipalityName', 'Percent African␣
       ↪Decimal']]

      lowest_percent_afpop_2017
```

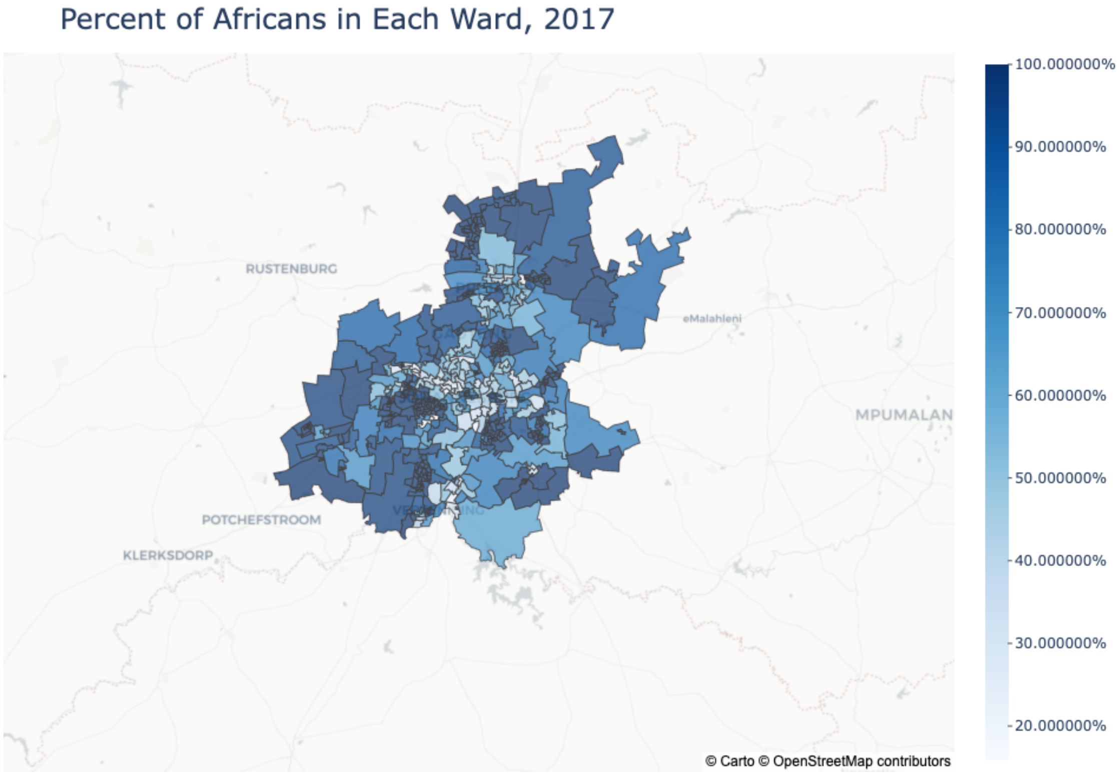
```
[38]:       WardID LocalMunicipalityName DistrictMunicipalityName  \
     48   79800018  City of Johannesburg     City of Johannesburg
     112  79800082  City of Johannesburg     City of Johannesburg
     39   79800009  City of Johannesburg     City of Johannesburg
     421  74202002               Midvaal                 Sedibeng
     485  79700038            Ekurhuleni               Ekurhuleni
     Percent African Decimal
48                  0.158730
112                 0.196970
39                  0.203390
421                 0.212121
485                 0.222222
```

Interestingly, the lowest percentage of Africans in a ward is now approximately 15%, a (seemingly) significant difference from 2011

Choropleth Maps I'm going to now convert this geodataframe into a geojson

[39]:
```
pop_wards_2017 = pop_group_17_gdf.to_crs(epsg=4326) # convert the coordinate␣
↪reference system to lat/long
pop_wards_2017_json = pop_group_17_gdf.__geo_interface__ #covert to geoJSON
```

[40]:
```
zmin = pop_wards_2017['Percent African Decimal'].min()
zmax = pop_wards_2017['Percent African Decimal'].max()

data = go.Choroplethmapbox(
        geojson = pop_wards_2017_json,
        locations = pop_wards_2017.index,
        z = pop_wards_2017['Percent African Decimal'],
        text = pop_wards_2017.WardID,
        colorbar=dict(thickness=20, ticklen=3, tickformat='%',outlinewidth=0),
        marker_line_width=1, marker_opacity=0.7, colorscale="Blues",
        zmin=zmin, zmax=zmax,
        hovertemplate = "<b>%{text}</b><br>" +
                    "%{z:.1%}<br>" +
                    "<extra></extra>")

# Set the layout for the map
layout = go.Layout(
title = {'text': f"Percent of Africans in Each Ward, 2017",
            'font': {'size':24}},
    mapbox1 = dict(
        domain = {'x': [0, 1],'y': [0, 1]},
        center = dict(lat=-26.270760, lon=28.112268),
        zoom = 7),
    autosize=True,
    height=650,
    margin=dict(l=0, r=0, t=40, b=0))

# Generate the map
fig=go.Figure(data=data, layout=layout)
fig.update_layout(mapbox_style="carto-positron")
fig.show()
#fig.write_html("Africans_ward_2017.html") #Again, I saved this as a comment to␣
 ↪prevent continous updates of the HTML
```



Now we have an interactive choropleth map for the percentage of African respondents in the GCRO 2017 data. We will use this in our final analysis

1.5 BRT Data

Because we are examining the impact of BRT development and use on social attitudes, I want to identify both the wards in which BRT use is highest and the wards through which the BRT passes

1.5.1 BRT Lines

We received BRT line data from the GCRO which I'd like to explore and then overlay on the 2017 interactive choropleth map.

[41]:
```
BRT_line.info()
```

```
<class 'geopandas.geodataframe.GeoDataFrame'>
RangeIndex: 11 entries, 0 to 10
Data columns (total 49 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
```

```
0   Name        11 non-null     object
1   Shape_Leng  11 non-null     float64
2   ID          11 non-null     int64
3   LENGTH      11 non-null     float64
4   DIR         11 non-null     int64
5   TYPE        8 non-null      object
6   BRT1        11 non-null     int64
7   BRT2        11 non-null     int64
8   BRT3        11 non-null     int64
9   BRT4        11 non-null     int64
10  BRT5        11 non-null     int64
11  BRT6        11 non-null     int64
12  BRT7        11 non-null     int64
13  BRT8        11 non-null     int64
14  BRT9        11 non-null     int64
15  BRT10       11 non-null     int64
16  BRT11       11 non-null     int64
17  BRT12       11 non-null     int64
18  BRT13       11 non-null     int64
19  BRT14       11 non-null     int64
20  BRT15       11 non-null     int64
21  BRT16       11 non-null     int64
22  BRT17       11 non-null     int64
23  BRT18       11 non-null     int64
24  BRT19       11 non-null     int64
25  BRT20       11 non-null     int64
26  BRT21       11 non-null     int64
27  BRT22       11 non-null     int64
28  LENGTH_F    11 non-null     float64
29  Year        6 non-null      object
30  Shape_Le_1  11 non-null     float64
31  ROUTE_ID    11 non-null     int64
32  ROUTE_NAME  2 non-null      object
33  DIRECTION   2 non-null      object
34  ROUTELENGT  11 non-null     float64
35  PHASE_1A    11 non-null     float64
36  PHASE_1B    11 non-null     float64
37  PHASE_1C    11 non-null     float64
38  PHASE_2     11 non-null     float64
39  PHASE_3     11 non-null     float64
40  PHASE_4     11 non-null     float64
41  PHASE_5     11 non-null     float64
42  PHASE_6     11 non-null     float64
43  STATUS      2 non-null      object
44  NETWORK_EV  2 non-null      object
45  ORIGIN      0 non-null      object
46  DESTINATIO  0 non-null      object
47  AVESPEED    0 non-null      object
```

```
 48  geometry    11 non-null     geometry
dtypes: float64(13), geometry(1), int64(25), object(10)
memory usage: 4.3+ KB
```

There are a lot of columns but only 11 rows! Let's take a closer look

[42]:
```
BRT_line.head(5)
```

[42]:
```
  Name  Shape_Leng  ID  LENGTH  DIR  TYPE  BRT1  BRT2  BRT3  BRT4  …  \
0  TSH    0.025628   0    0.00    0  None     0     0     0     0  …
1  TSH    0.059222   6    6.50    0   BRT     1     0     0     0  …
2  TSH    0.036972  23    5.14    0   BRT     1     0     0     0  …
3  TSH    0.007126  21    0.79    0   BRT     1     0     0     0  …
4  TSH    0.011501   4    1.25    0   BRT     1     0     0     0  …

   PHASE_3  PHASE_4  PHASE_5  PHASE_6  STATUS  NETWORK_EV  ORIGIN  DESTINATIO  \
0      0.0      0.0      0.0      0.0    None        None    None        None
1      0.0      0.0      0.0      0.0    None        None    None        None
2      0.0      0.0      0.0      0.0    None        None    None        None
3      0.0      0.0      0.0      0.0    None        None    None        None
4      0.0      0.0      0.0      0.0    None        None    None        None

   AVESPEED                                           geometry
0      None  LINESTRING (28.22520 -25.75598, 28.22529 -25.7…
1      None  LINESTRING (28.18702 -25.68882, 28.18740 -25.6…
2      None  LINESTRING (28.19085 -25.75045, 28.19212 -25.7…
3      None  LINESTRING (28.19029 -25.74334, 28.19085 -25.7…
4      None  LINESTRING (28.18304 -25.67811, 28.18342 -25.6…

[5 rows x 49 columns]
```

Trim the data I want to trim this data to keep only the columns I will use

[43]:
```
BRT_line = BRT_line[['Name', 'Shape_Leng', 'ID', 'geometry']].copy()
```

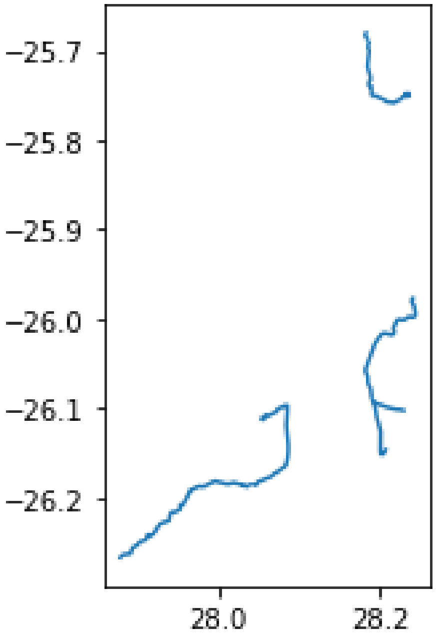
[44]:
```
BRT_line
```

[44]:
```
   Name  Shape_Leng  ID                                           geometry
0   TSH    0.025628   0  LINESTRING (28.22520 -25.75598, 28.22529 -25.7…
1   TSH    0.059222   6  LINESTRING (28.18702 -25.68882, 28.18740 -25.6…
2   TSH    0.036972  23  LINESTRING (28.19085 -25.75045, 28.19212 -25.7…
3   TSH    0.007126  21  LINESTRING (28.19029 -25.74334, 28.19085 -25.7…
4   TSH    0.011501   4  LINESTRING (28.18304 -25.67811, 28.18342 -25.6…
5   EKU    0.000000  67  LINESTRING (28.19112 -26.08927, 28.19046 -26.0…
6   EKU    0.000000  82  LINESTRING (28.19185 -26.09092, 28.19209 -26.0…
7   EKU    0.000000   0  LINESTRING (28.19112 -26.08927, 28.19299 -26.0…
8   EKU    0.000000   0  LINESTRING (28.20917 -26.14441, 28.20929 -26.1…
9   JHB    0.000000   0  LINESTRING (27.87592 -26.26884, 27.87695 -26.2…
10  JHB    0.000000   0  LINESTRING (28.05931 -26.10887, 28.05923 -26.1…
```

Now that the data is trimmed, let's see what it looks like plotted

```
[45]: BRT_line.plot()
```

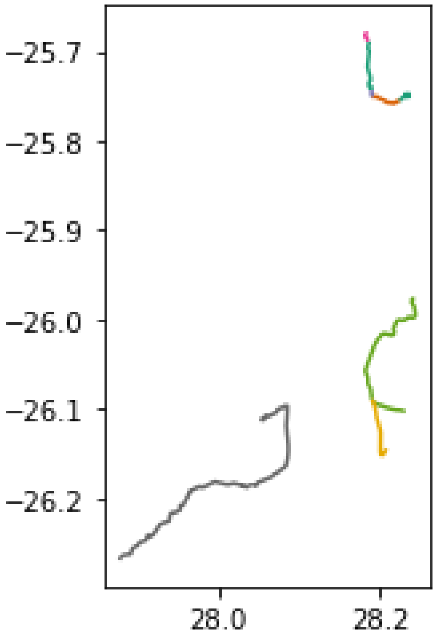
```
[45]: <AxesSubplot:>
```



I know that there are three BRT systems in the Gauteng region and we can see three distinct lines here! Let's look at them in different colors

```
[46]: BRT_line.plot(
                  cmap='Dark2',
                  markersize=10,
                      legend=True)
```

```
[46]: <AxesSubplot:>
```



By changing the color scheme, I can see that the BRT in Tshwane and Ekurhuleni have different routes. I want to be able to overlay the BRT lines on both my static and interactive maps. I have been successful in overlaying the lines on static maps but now want to overlay them on my plotly interactive maps

1.5.2 Converting BRT line geometry to lat/lon

I read on stackoverflow that in order to plot the BRT line data on the choropleth map, I need to convert the geometry linestring to lat/lon.

[47]:

```
import numpy as np

import shapely.geometry
```

[48]:

```
lats = []
lons = []
names = []

for feature in BRT_line.geometry:
    if isinstance(feature, shapely.geometry.linestring.LineString):
        linestrings = [feature]
    else:
        continue
    for linestring in linestrings:
        x, y = linestring.xy
        lats = np.append(lats, y)
        lons = np.append(lons, x)
        lats = np.append(lats, None)
        lons = np.append(lons, None)
```

Since this is new code, I want to see if and how the data has changed

[49]:
```
BRT_line
```

[49]:
```
   Name  Shape_Leng  ID                                           geometry
0   TSH    0.025628   0  LINESTRING (28.22520 -25.75598, 28.22529 -25.7…
1   TSH    0.059222   6  LINESTRING (28.18702 -25.68882, 28.18740 -25.6…
2   TSH    0.036972  23  LINESTRING (28.19085 -25.75045, 28.19212 -25.7…
3   TSH    0.007126  21  LINESTRING (28.19029 -25.74334, 28.19085 -25.7…
4   TSH    0.011501   4  LINESTRING (28.18304 -25.67811, 28.18342 -25.6…
5   EKU    0.000000  67  LINESTRING (28.19112 -26.08927, 28.19046 -26.0…
6   EKU    0.000000  82  LINESTRING (28.19185 -26.09092, 28.19209 -26.0…
7   EKU    0.000000   0  LINESTRING (28.19112 -26.08927, 28.19299 -26.0…
8   EKU    0.000000   0  LINESTRING (28.20917 -26.14441, 28.20929 -26.1…
9   JHB    0.000000   0  LINESTRING (27.87592 -26.26884, 27.87695 -26.2…
10  JHB    0.000000   0  LINESTRING (28.05931 -26.10887, 28.05923 -26.1…
```

The dataframe looks the same…so I'd like to plot it again, this time using Plotly to see if the code was successful

[50]:
```
fig = px.line_geo(BRT_line, lat=lats, lon=lons)
fig.update_geos(fitbounds="locations", visible=False)
fig.update_layout(margin={"r":0,"t":0,"l":0,"b":0})
fig.show()
```

Yay! The data is now interactive and when you hover over the lines, you can see the lat/lon coordinates for the entire line.

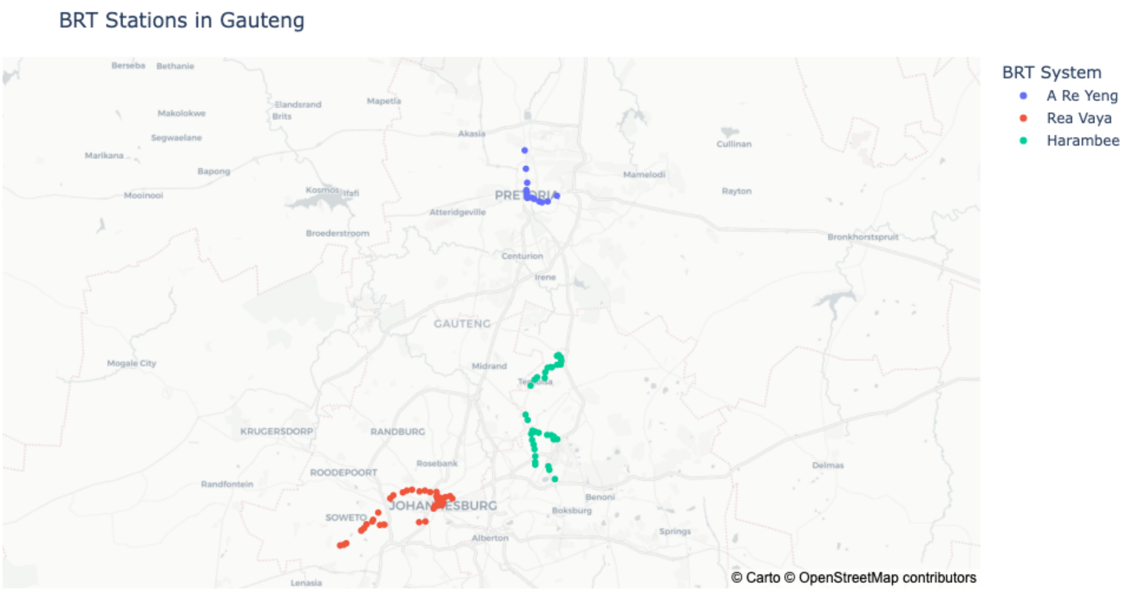
1.5.3 BRT Stations

Now that we have the interactive BRT lines, I want to create an interactive map of the BRT stations. I handcoded the BRT stations outside of python (using geojson.io) based off of the BRT station names for Rea Vaya, A Re Yang, and Harambee. I tried my best to map them accurately, however they should be considered approximate bus station locations!

[51]:
```
BRT_stations.head(5)
```

[51]:
```
  marker-color marker-size marker-symbol        BRT Route Name  \
0      #f28ce5       small           bus  A Re Yeng     TSH T1
1      #f28ce5       small           bus  A Re Yeng     TSH T1
2      #f28ce5       small           bus  A Re Yeng     TSH T1
3      #f28ce5       small           bus  A Re Yeng     TSH T1
4      #f28ce5       small           bus  A Re Yeng     TSH T1

         Stop Name                    geometry
0    Church Square  POINT (28.18863 -25.74705)
1  Central Station  POINT (28.18907 -25.75059)
2        Nana Sita  POINT (28.19626 -25.75013)
3     Ruth Mompati  POINT (28.20015 -25.75201)
4   Mahatma Gandhi  POINT (28.20840 -25.75565)
```

[52]:
```
fig = px.scatter_mapbox(BRT_stations,
                        lat=BRT_stations.geometry.y,
                        lon=BRT_stations.geometry.x,
                        color="BRT",
                        hover_name="Stop Name",
                        mapbox_style="carto-positron",
                        title="BRT Stations in Gauteng",
                        labels={"BRT": "BRT System"},
                        center = {"lat":-25.935266, "lon": 28.1296512},
                        zoom=8.5)

fig.update_layout(height=500, margin={"r":0,"t":50,"l":0,"b":0})
fig.show()
fig.write_html("BRT_stations_2017.html")
```



I was having difficulty overlaying the station maps on a choropleth map, and ultimately was not succesful in overlaying them so we will be using the interactive BRT lines for interactive maps and will use this interactive map for readers interested in exploring the different lines and their respective stations

1.6 Interactive Choropleth maps with BRT lines

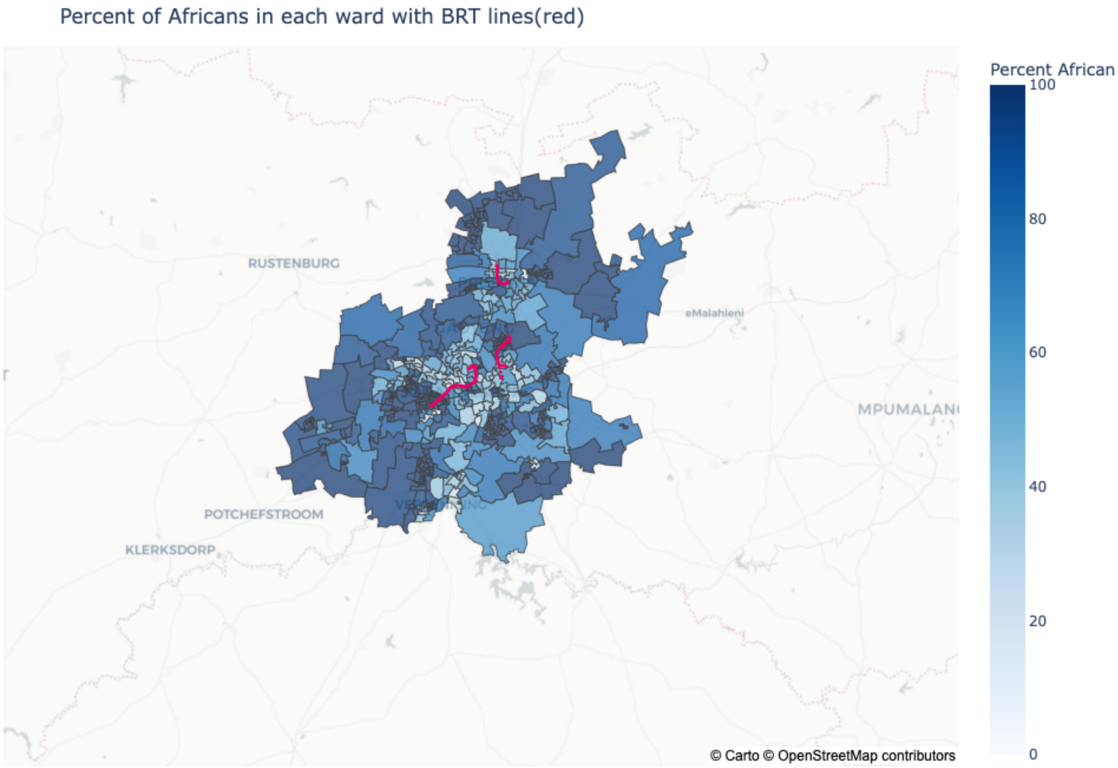
We want to examine racial attitudes in wards that the BRT passes through and in which BRT use is highest. To do so, we need to create interactive maps because they allow us to see each ward's ID number.

Note: For some reason, I kept getting continous errors when running the following code. After making seemingly a million tweaks, it finally worked!

1.6.1 Population of Africans with BRT lines overlayed

[53]:
```
fig = px.choropleth_mapbox(pop_wards_2017, geojson=pop_wards_2017_json,␣
 ↪locations=pop_wards_2017.index, color='Percent African',
                              color_continuous_scale="Blues",
                              range_color=(0, 100),
                              hover_name= pop_wards_2017['WardID'],
                              mapbox_style="carto-positron",
                              zoom=7, center = {"lat":-26.270760, "lon": 28.
 ↪112268},
                              title="Percent of Africans in each ward with BRT␣
 ↪lines(red)",
                              opacity=0.7,
                             )
```

```
fig.add_scattermapbox(
    lat = lats,
    lon = lons,
    marker_size=3,
    marker_color='rgb(235, 0, 100)'
)
fig.update_layout(height=650, margin={"r":0,"t":40,"l":0,"b":0})
fig.show()
#fig.write_html("BRT Ward.html")
```


Percent of Africans in each ward with BRT lines(red)
RUSTENBURG
eMalahleni
MPUMALANGA
POTCHEFSTROOM
KLERKSDORP
© Carto © OpenStreetMap contributors
Percent African
100
80
60
40
20
0

We can now see the wards that the BRT line passes through, which will be useful for our final analysis. I manually identified the wards that have the BRT lines running through them and tracking it outside of Python to then use in our analysis

1.6.2 BRT Use

I want to create a choropleth map of BRT use in the region and then overlay the BRT line. We hypothesize that BRT use will be higher in wards that have the BRT passing through

```
[54]: BRT_use = pd.crosstab(index=gdf_2017['WardID'],
                            columns=gdf_2017['Q5_11_BRT_Freq'],
                                                margins=True,
                           margins_name='Total Number')
```

```
BRT_use
```

```
[54]: Q5_11_BRT_Freq  A few times a month  Every few months  Most days  Never  \
      WardID
      74201001                          0                 0          0     35
      74201002                          2                 1          1     33
      74201003                          1                 0          0     32
      74201004                          0                 0          0     33
      74201005                          0                 0          0     30
      ...                            ...             ...      ...  ...
      79900104                          0                 1          1     29
      79900105                          0                 0          0     30
      79900106                          2                 5          0     30
      79900107                          3                 2          7     30
      Total Number                    887               836        460  21400

      Q5_11_BRT_Freq  Once or twice a week  Total Number
      WardID
      74201001                           0            35
      74201002                           0            37
      74201003                           0            33
      74201004                           1            34
      74201005                           0            30
      ...                             ...         ...
      79900104                           1            32
      79900105                           0            30
      79900106                           0            37
      79900107                           2            44
      Total Number                     341         23924

      [530 rows x 6 columns]
```

Though respondents selected the frequency of their BRT use from a list of 5 options, we will be analyzing BRT use at any frequency, given that BRT use is relatively small compared to other modes of transportation. I want to create a new column of total BRT use by adding up the number of respondents that use BRT in each ward

```
[55]: BRT_use['Use BRT'] = BRT_use['A few times a month']+BRT_use['Every few␣
       ↪months']+BRT_use['Most days']+BRT_use['Once or twice a week']

      BRT_use
```

```
[55]: Q5_11_BRT_Freq  A few times a month  Every few months  Most days  Never  \
      WardID
      74201001                          0                 0          0     35
      74201002                          2                 1          1     33
```

```
74201003                           1                 0          0     32
74201004                           0                 0          0     33
74201005                           0                 0          0     30
...                             ...               ...        ...    ...
79900104                           0                 1          1     29
79900105                           0                 0          0     30
79900106                           2                 5          0     30
79900107                           3                 2          7     30
Total Number                     887               836        460  21400

Q5_11_BRT_Freq  Once or twice a week  Total Number  Use BRT
WardID
74201001                           0            35        0
74201002                           0            37        4
74201003                           0            33        1
74201004                           1            34        1
74201005                           0            30        0
...                              ...           ...      ...
79900104                           1            32        3
79900105                           0            30        0
79900106                           0            37        7
79900107                           2            44       14
Total Number                     341         23924     2524

[530 rows x 7 columns]
```

Now that I have total BRT use summed, I want to create a proportion and percentage column

```
[56]: BRT_use['YES Use BRT']=BRT_use['Use BRT']/BRT_use['Total Number']

      BRT_use
```

```
[56]: Q5_11_BRT_Freq  A few times a month  Every few months  Most days  Never  \
      WardID
      74201001                           0                 0          0     35
      74201002                           2                 1          1     33
      74201003                           1                 0          0     32
      74201004                           0                 0          0     33
      74201005                           0                 0          0     30
      ...                             ...               ...        ...    ...
      79900104                           0                 1          1     29
      79900105                           0                 0          0     30
      79900106                           2                 5          0     30
      79900107                           3                 2          7     30
      Total Number                     887               836        460  21400

      Q5_11_BRT_Freq  Once or twice a week  Total Number  Use BRT  YES Use BRT
```

```
WardID
74201001                           0            35         0      0.000000
74201002                           0            37         4      0.108108
74201003                           0            33         1      0.030303
74201004                           1            34         1      0.029412
74201005                           0            30         0      0.000000
…                               …           …       …           …
79900104                           1            32         3      0.093750
79900105                           0            30         0      0.000000
79900106                           0            37         7      0.189189
79900107                           2            44        14      0.318182
Total Number                     341         23924      2524      0.105501

[530 rows x 8 columns]
```

```
[57]: BRT_use['YES Use BRT Percent'] = BRT_use['YES Use BRT']*100
```

I now want to create a column of respondents that **do not** use BRT

```
[58]: BRT_use['NO BRT use']=BRT_use['Never']/BRT_use['Total Number']

      BRT_use
```

```
[58]: Q5_11_BRT_Freq  A few times a month  Every few months  Most days  Never  \
      WardID
      74201001                          0                 0          0     35
      74201002                          2                 1          1     33
      74201003                          1                 0          0     32
      74201004                          0                 0          0     33
      74201005                          0                 0          0     30
      …                              …                …         …     …
      79900104                          0                 1          1     29
      79900105                          0                 0          0     30
      79900106                          2                 5          0     30
      79900107                          3                 2          7     30
      Total Number                    887               836        460  21400

      Q5_11_BRT_Freq  Once or twice a week  Total Number  Use BRT  YES Use BRT  \
      WardID
      74201001                           0            35         0      0.000000
      74201002                           0            37         4      0.108108
      74201003                           0            33         1      0.030303
      74201004                           1            34         1      0.029412
      74201005                           0            30         0      0.000000
      …                               …           …       …           …
      79900104                           1            32         3      0.093750
      79900105                           0            30         0      0.000000
```

```
79900106                           0            37        7     0.189189
79900107                           2            44       14     0.318182
Total Number                     341         23924     2524     0.105501

Q5_11_BRT_Freq  YES Use BRT Percent  NO BRT use
WardID
74201001                   0.000000    1.000000
74201002                  10.810811    0.891892
74201003                   3.030303    0.969697
74201004                   2.941176    0.970588
74201005                   0.000000    1.000000
…                             …         …
79900104                   9.375000    0.906250
79900105                   0.000000    1.000000
79900106                  18.918919    0.810811
79900107                  31.818182    0.681818
Total Number              10.550075    0.894499

[530 rows x 10 columns]
```

[59]:
```
BRT_use['No BRT Use Percent'] = BRT_use['NO BRT use']*100
```

Now that we have the percentages of BRT use and no BRT use, I will save them as a new dataframe

[60]:
```
BRT_yes_no = BRT_use[['YES Use BRT Percent', 'No BRT Use Percent']]

BRT_yes_no
```

[60]:
```
Q5_11_BRT_Freq  YES Use BRT Percent  No BRT Use Percent
WardID
74201001                   0.000000          100.000000
74201002                  10.810811           89.189189
74201003                   3.030303           96.969697
74201004                   2.941176           97.058824
74201005                   0.000000          100.000000
…                             …                   …
79900104                   9.375000           90.625000
79900105                   0.000000          100.000000
79900106                  18.918919           81.081081
79900107                  31.818182           68.181818
Total Number              10.550075           89.449925

[530 rows x 2 columns]
```

However, I want to drop the “total number” column from the dataframe

[61]:
```
BRT_yes_no = BRT_yes_no.drop('Total Number')
```

In order to map BRT use, I'll merge it with the 2017 wards data

```
[62]: BRT_use_2017 = wards_2017.merge(BRT_yes_no, on='WardID')

      BRT_use_2017
```

```
[62]:      OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
      0        1504           GT      Gauteng                   EKU         60
      1        1505           GT      Gauteng                   EKU         61
      2        1506           GT      Gauteng                   EKU         62
      3        1507           GT      Gauteng                   EKU         63
      4        1508           GT      Gauteng                   EKU         64
      ..        …          …          …                   …        …
      524      4319           GT      Gauteng                   EKU        108
      525      4320           GT      Gauteng                   EKU        109
      526      4321           GT      Gauteng                   EKU        110
      527      4322           GT      Gauteng                   EKU        111
      528      4323           GT      Gauteng                   EKU        112

             WardID LocalMunicipalityName DistrictMunicipalityCode  \
      0    79700060            Ekurhuleni                      EKU
      1    79700061            Ekurhuleni                      EKU
      2    79700062            Ekurhuleni                      EKU
      3    79700063            Ekurhuleni                      EKU
      4    79700064            Ekurhuleni                      EKU
      ..        …                   …                      …
      524  79700108            Ekurhuleni                      EKU
      525  79700109            Ekurhuleni                      EKU
      526  79700110            Ekurhuleni                      EKU
      527  79700111            Ekurhuleni                      EKU
      528  79700112            Ekurhuleni                      EKU

          DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
      0                 Ekurhuleni  2016  3.898607e+06   11472.007890
      1                 Ekurhuleni  2016  2.040419e+07   24911.970404
      2                 Ekurhuleni  2016  5.823267e+07   42030.549363
      3                 Ekurhuleni  2016  3.332302e+06   10253.147328
      4                 Ekurhuleni  2016  1.239711e+07   18521.992239
      ..                      …   …          …          …
      524               Ekurhuleni  2016  3.986026e+06   12293.042422
      525               Ekurhuleni  2016  7.126183e+06   17501.893757
      526               Ekurhuleni  2016  8.281005e+06   15886.916039
      527               Ekurhuleni  2016  2.570824e+07   29656.849051
      528               Ekurhuleni  2016  6.723852e+06   14259.004191

                                                geometry  YES Use BRT Percent  \
      0    POLYGON ((28.16493 -26.35885, 28.16632 -26.358…             3.773585
      1    POLYGON ((28.13552 -26.40783, 28.13665 -26.408…            7.407407
      2    POLYGON ((28.24732 -26.38152, 28.25052 -26.386…            3.846154
      3    POLYGON ((28.16205 -26.37103, 28.16219 -26.371…           10.204082
      4    POLYGON ((28.22547 -26.35844, 28.22591 -26.358…            3.773585
      ..                                                 …                   …
      524  POLYGON ((28.19092 -26.37677, 28.19174 -26.377…            7.843137
      525  POLYGON ((28.43689 -26.10593, 28.43703 -26.106…            7.547170
      526  POLYGON ((28.39511 -26.14457, 28.39570 -26.145…            8.620690
      527  POLYGON ((28.43582 -26.31314, 28.43659 -26.313…            0.000000
      528  POLYGON ((28.35914 -26.35703, 28.35931 -26.358…            1.694915

           No BRT Use Percent
      0             96.226415
      1             92.592593
      2             96.153846
      3             89.795918
      4             96.226415
      ..                  …
      524           92.156863
      525           92.452830
      526           91.379310
      527          100.000000
      528           98.305085

      [529 rows x 15 columns]
```

It looks like the merge was successful!

1.6.3 Exploring BRT Use

I want to see the wards in which BRT use is highest and lowest

```
[63]: BRT_use_highest = BRT_use_2017.sort_values(by="YES Use BRT Percent",␣
       ↪ascending=False).head(10)

      BRT_use_highest
```

```
[63]:     OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
      59      2568           GT      Gauteng                   JHB         29
      63      2572           GT      Gauteng                   JHB         33
      42      2551           GT      Gauteng                   JHB         12
      76      2585           GT      Gauteng                   JHB         46
      55      2564           GT      Gauteng                   JHB         25
      61      2570           GT      Gauteng                   JHB         31
      90      2599           GT      Gauteng                   JHB         60
      69      2578           GT      Gauteng                   JHB         39
      99      2608           GT      Gauteng                   JHB         69
      60      2569           GT      Gauteng                   JHB         30
      WardID LocalMunicipalityName DistrictMunicipalityCode  \
59  79800029  City of Johannesburg                      JHB
63  79800033  City of Johannesburg                      JHB
42  79800012  City of Johannesburg                      JHB
76  79800046  City of Johannesburg                      JHB
55  79800025  City of Johannesburg                      JHB
61  79800031  City of Johannesburg                      JHB
90  79800060  City of Johannesburg                      JHB
69  79800039  City of Johannesburg                      JHB
99  79800069  City of Johannesburg                      JHB
60  79800030  City of Johannesburg                      JHB

   DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
59     City of Johannesburg  2016  6.702357e+06   13310.759165
63     City of Johannesburg  2016  3.843595e+06   10476.516439
42     City of Johannesburg  2016  2.946026e+06    9074.125560
76     City of Johannesburg  2016  4.737237e+06   11810.295027
55     City of Johannesburg  2016  5.999320e+06   13354.510774
61     City of Johannesburg  2016  2.184496e+06    8753.932909
90     City of Johannesburg  2016  7.107358e+06   15169.436463
69     City of Johannesburg  2016  4.312237e+06   10606.390622
99     City of Johannesburg  2016  5.913493e+06   15658.668156
60     City of Johannesburg  2016  3.185999e+06   10554.740483

                                             geometry  YES Use BRT Percent  \
59  POLYGON ((27.95300 -26.21879, 27.95342 -26.218…             54.166667
63  POLYGON ((27.85990 -26.25643, 27.85992 -26.257…             50.847458
42  POLYGON ((27.85868 -26.27761, 27.86215 -26.279…             50.000000
76  POLYGON ((27.87445 -26.23159, 27.87516 -26.232…             47.272727
55  POLYGON ((27.91362 -26.24990, 27.91389 -26.249…             46.774194
61  POLYGON ((27.92653 -26.22928, 27.92691 -26.229…             44.897959
90  POLYGON ((28.03264 -26.18669, 28.03288 -26.186…             44.615385
69  POLYGON ((27.92109 -26.21904, 27.92116 -26.219…             43.750000
99  POLYGON ((27.99919 -26.17160, 27.99917 -26.171…             42.592593
60  POLYGON ((27.92039 -26.23825, 27.92045 -26.238…             41.818182

    No BRT Use Percent
59           45.833333
63           49.152542
42           50.000000
76           52.727273
55           53.225806
61           55.102041
90           55.384615
69           56.250000
99           57.407407
```

```
60          58.181818
```

I want to trim the columns to only what I need

```
[64]: BRT_use_highest= BRT_use_highest[['WardID', 'LocalMunicipalityName',␣
       ↪'DistrictMunicipalityName', 'YES Use BRT Percent']]

      BRT_use_highest
```

```
[64]:       WardID LocalMunicipalityName DistrictMunicipalityName  \
      59  79800029  City of Johannesburg     City of Johannesburg
      63  79800033  City of Johannesburg     City of Johannesburg
      42  79800012  City of Johannesburg     City of Johannesburg
      76  79800046  City of Johannesburg     City of Johannesburg
      55  79800025  City of Johannesburg     City of Johannesburg
      61  79800031  City of Johannesburg     City of Johannesburg
      90  79800060  City of Johannesburg     City of Johannesburg
      69  79800039  City of Johannesburg     City of Johannesburg
      99  79800069  City of Johannesburg     City of Johannesburg
      60  79800030  City of Johannesburg     City of Johannesburg

          YES Use BRT Percent
      59            54.166667
      63            50.847458
      42            50.000000
      76            47.272727
      55            46.774194
      61            44.897959
      90            44.615385
      69            43.750000
      99            42.592593
      60            41.818182
```

From the table above, we can see that BRT use is the highest in Johannesburg.

Now I will explore the wards with the lowest BRT use

```
[65]: BRT_use_lowest = BRT_use_2017.sort_values(by="No BRT Use Percent",␣
       ↪ascending=False).head(10)

      BRT_use_lowest
```

```
[65]:      OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
      418      4213           GT      Gauteng                 GT421         44
      419      4214           GT      Gauteng                 GT421         45
      320      3851           GT      Gauteng                 GT481         39
      312      3843           GT      Gauteng                 GT481         31
      388      4183           GT      Gauteng                 GT421         14
```

```
389      4184           GT      Gauteng                 GT421         15
390      4185           GT      Gauteng                 GT421         16
311      3842           GT      Gauteng                 GT481         30
309      3840           GT      Gauteng                 GT481         28
307      3777           GT      Gauteng                 GT485         35

       WardID LocalMunicipalityName DistrictMunicipalityCode  \
418  74201044              Emfuleni                     DC42
419  74201045              Emfuleni                     DC42
320  74801039           Mogale City                     DC48
312  74801031           Mogale City                     DC48
388  74201014              Emfuleni                     DC42
389  74201015              Emfuleni                     DC42
390  74201016              Emfuleni                     DC42
311  74801030           Mogale City                     DC48
309  74801028           Mogale City                     DC48
307  74205035        Rand West City                     DC48

    DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
418                 Sedibeng  2016  4.761278e+06   13449.434506
419                 Sedibeng  2016  7.117027e+07   37262.654049
320                West Rand  2016  3.180230e+08  100321.254092
312                West Rand  2016  2.515273e+08   82753.822200
388                 Sedibeng  2016  3.602065e+06    8982.118487
389                 Sedibeng  2016  2.856751e+07   26324.569849
390                 Sedibeng  2016  3.708146e+07   36565.083948
311                West Rand  2016  1.147148e+08   57707.915574
309                West Rand  2016  7.648468e+06   18111.940038
307                West Rand  2016  1.223508e+07   21544.061485

                                              geometry  YES Use BRT Percent  \
418  POLYGON ((27.84854 -26.52579, 27.84919 -26.528…                 0.0
419  POLYGON ((27.92167 -26.56789, 27.92210 -26.568…                 0.0
320  POLYGON ((27.86093 -25.94484, 27.85577 -25.948…                 0.0
312  POLYGON ((27.54490 -25.99084, 27.54509 -25.991…                 0.0
388  POLYGON ((27.86692 -26.68585, 27.86778 -26.687…                 0.0
389  POLYGON ((27.95406 -26.64993, 27.95643 -26.651…                 0.0
390  POLYGON ((27.98077 -26.55415, 27.98086 -26.554…                 0.0
311  POLYGON ((27.70048 -26.06088, 27.70052 -26.061…                 0.0
309  POLYGON ((27.84682 -26.06431, 27.84773 -26.064…                 0.0
307  POLYGON ((27.70385 -26.28741, 27.70384 -26.288…                 0.0

     No BRT Use Percent
418               100.0
419               100.0
320               100.0
312               100.0
```

```
388                100.0
389                100.0
390                100.0
311                100.0
309                100.0
307                100.0
```

[66]:

```
ward_low_BRT_use_2011 = BRT_use_2017[BRT_use_2017['No BRT Use Percent']==100]
```

[67]:

```
print ('There are ' + str(len(ward_low_BRT_use_2011)) + ' wards in which BRT␣
 ↪use is 0%')
```

```
There are 68 wards in which BRT use is 0%
```

As we can see from above, there are 68 wards in which BRT use is 0. I would like to see the wards in which BRT use is the lowest. Though 68 wards is a lot to scroll through!

[68]:

```
ward_low_BRT_use_2017 = ward_low_BRT_use_2011[['WardID',␣
 ↪'LocalMunicipalityName', 'No BRT Use Percent']]
pd.set_option('display.max_rows',68)
ward_low_BRT_use_2017
```

[68]:

```
       WardID LocalMunicipalityName  No BRT Use Percent
6    79700066            Ekurhuleni               100.0
9    79700069            Ekurhuleni               100.0
27   79700087            Ekurhuleni               100.0
34   79800004  City of Johannesburg               100.0
35   79800005  City of Johannesburg               100.0
109  79800079  City of Johannesburg               100.0
207  79900043       City of Tshwane               100.0
266  79900103       City of Tshwane               100.0
268  79900105       City of Tshwane               100.0
273  74205001        Rand West City               100.0
275  74205003        Rand West City               100.0
276  74205004        Rand West City               100.0
279  74205007        Rand West City               100.0
282  74205010        Rand West City               100.0
285  74205013        Rand West City               100.0
286  74205014        Rand West City               100.0
292  74205020        Rand West City               100.0
298  74205026        Rand West City               100.0
299  74205027        Rand West City               100.0
301  74205029        Rand West City               100.0
303  74205031        Rand West City               100.0
305  74205033        Rand West City               100.0
307  74205035        Rand West City               100.0
309  74801028           Mogale City               100.0
311  74801030           Mogale City               100.0
```

```
312  74801031           Mogale City               100.0
320  74801039           Mogale City               100.0
324  74804004         Merafong City               100.0
325  74804005         Merafong City               100.0
328  74804008         Merafong City               100.0
329  74804009         Merafong City               100.0
332  74804012         Merafong City               100.0
334  74804014         Merafong City               100.0
337  74804017         Merafong City               100.0
342  74804022         Merafong City               100.0
345  74804025         Merafong City               100.0
347  74804027         Merafong City               100.0
348  74804028         Merafong City               100.0
352  74801004           Mogale City               100.0
353  74801005           Mogale City               100.0
358  74801010           Mogale City               100.0
364  74801016           Mogale City               100.0
366  74801018           Mogale City               100.0
368  74801020           Mogale City               100.0
369  74801021           Mogale City               100.0
375  74201001              Emfuleni               100.0
379  74201005              Emfuleni               100.0
388  74201014              Emfuleni               100.0
389  74201015              Emfuleni               100.0
390  74201016              Emfuleni               100.0
397  74201023              Emfuleni               100.0
418  74201044              Emfuleni               100.0
419  74201045              Emfuleni               100.0
424  74202005               Midvaal               100.0
430  74202011               Midvaal               100.0
431  74202012               Midvaal               100.0
434  74202015               Midvaal               100.0
435  74203001                Lesedi               100.0
437  74203003                Lesedi               100.0
438  74203004                Lesedi               100.0
440  74203006                Lesedi               100.0
441  74203007                Lesedi               100.0
444  74203010                Lesedi               100.0
445  74203011                Lesedi               100.0
446  74203012                Lesedi               100.0
473  79700026            Ekurhuleni               100.0
512  79700096            Ekurhuleni               100.0
527  79700111            Ekurhuleni               100.0
```

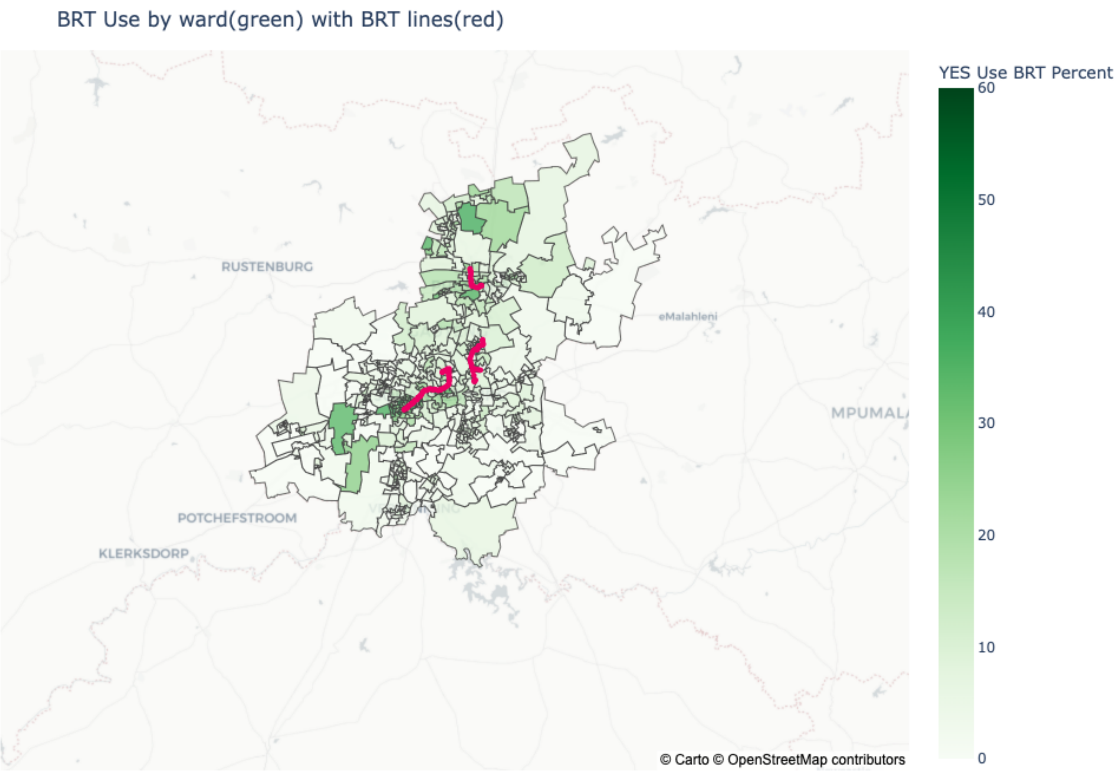
Choropleth map And now, to create an interactive Plotly map, I'll convert the data to geojson and lat/lon

[69]:

```
BRT_wards_2017 = BRT_use_2017.to_crs(epsg=4326) # convert the coordinate␣
 ↪reference system to lat/long
BRT_wards_2017_json = BRT_use_2017.__geo_interface__ #covert to geoJSON
```

[70]:

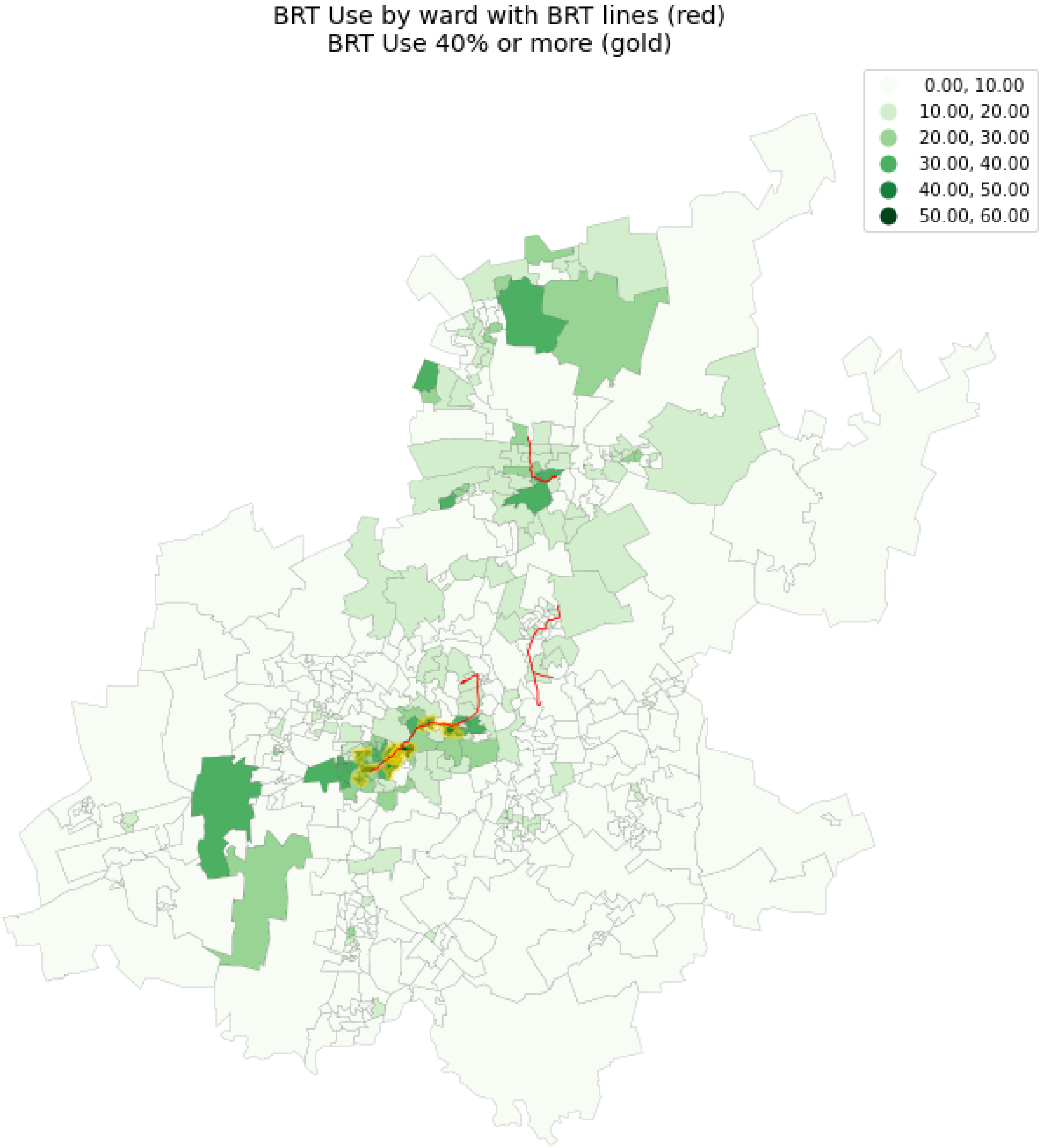
```
fig = px.choropleth_mapbox(BRT_wards_2017, geojson=BRT_wards_2017_json,␣
 ↪locations=BRT_wards_2017.index, color='YES Use BRT Percent',
                           color_continuous_scale="Greens",
                           range_color=(0, 60),
                           hover_name= BRT_wards_2017['WardID'],
                           mapbox_style="carto-positron",
                           zoom=7, center = {"lat":-26.270760, "lon": 28.
 ↪112268},
                           opacity=0.8,
                           title="BRT Use by ward(green) with BRT lines(red)"
                          )

fig.add_scattermapbox(
    lat = lats,
    lon = lons,
    marker_size=5,
    marker_color='rgb(235, 0, 100)'
)

fig.update_layout(height=650, margin={"r":0,"t":40,"l":0,"b":0})
fig.show()
#fig.write_html("BRT use_wards.html")
```



The interactive map allows us to the use of BRT along with the BRT lines, and as hypothesized BRT use is higher in wards that have a BRT line. There are a few wards (74205025,74205030,79900095,79900030) that have a pretty high (~30%) BRT use but aren't adjacent to a line. I want to highlight the top 10 wards in which BRT use is highest, but I haven't been able to figure out how I can do so in an interactive map, so instead I'll be creating a static map

```
[71]: fig,ax = plt.subplots(figsize=(12,12))

      BRT_use_2017.plot(ax=ax,
               column=BRT_use_2017['YES Use BRT Percent'],
               legend=True,
               scheme='user_defined',
               classification_kwds={'bins':[10,20,30,40,50,60]},
               cmap='Greens',
                        edgecolor='black',
                        linewidth=0.1
              )

      BRT_use_2017[BRT_use_2017['YES Use BRT Percent'] >= 40].boundary.plot(ax=ax,
              alpha=0.5,
              linewidth=3,
              hatch="///",
              color='gold'
```

```
        )

BRT_line.plot(ax=ax, color='red', linewidth=0.8)

ax.set_title('BRT Use by ward with BRT lines (red)\n' +  'BRT Use 40% or more␣
 ↪(gold)', fontsize=14)
ax.axis('off');
fig.savefig('BRT_use.png')
```



As we identified in the interactive map, we can see that the wards in which BRT is greater than

40% are closest to the Rea Vaya in Johannesburg and is generally higher in areas that are near the BRT. I want to see the list of ward numbers

[72]:
```
print (BRT_use_2017[['WardID', 'YES Use BRT Percent']][BRT_use_2017['YES Use␣
↪BRT Percent'] >= 40])
```

```
      WardID  YES Use BRT Percent
42  79800012            50.000000
55  79800025            46.774194
59  79800029            54.166667
60  79800030            41.818182
61  79800031            44.897959
63  79800033            50.847458
69  79800039            43.750000
76  79800046            47.272727
90  79800060            44.615385
99  79800069            42.592593
```

Now that we have the wards with BRT use more than 40%, we can see examine the atittudes in these wards

1.7 Social atittudes in wards that the BRT passes through

I will import the data for social atittudes by ward that Yasmina created. Each dataset shows the mean attitude about attitudes toward foreigners and about trust between Black and White individuals. I want to compare the attitudes of respondents in the wards the BRT passes through to see if they have improved over time

[73]:
```
BRT_attitudes_2011 = pd.read_csv('BRT_wards_attitudes_2011.csv')
```

[74]:
```
BRT_attitudes_2017 = pd.read_csv('BRT_wards_attitudes_2017.csv')
```

1.7.1 2011

Let’s explore the data

[75]:
```
BRT_attitudes_2011.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 48 entries, 0 to 47
Data columns (total 4 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   WardID            48 non-null     int64  
 1   BRT Line          48 non-null     object 
 2   att_foreign_mean  48 non-null     float64
 3   bw_trust_mean     47 non-null     float64
dtypes: float64(2), int64(1), object(1)
memory usage: 1.6+ KB
```

```
[76]: BRT_attitudes_2011.head()
```

```
[76]:      WardID  BRT Line  att_foreign_mean  bw_trust_mean
      0  79800019  Rea Vaya          0.363636       1.139535
      1  79800033  Rea Vaya          0.205882       0.901961
      2  79800037  Rea Vaya          0.162791       1.000000
      3  79800038  Rea Vaya          0.145833       1.166667
      4  79800030  Rea Vaya          0.081081       0.947368
```

I want to merge this data with ward geospatial data but first need to convert the WardID column from object to int

```
[77]: wards_2011["WardID"] = pd.to_numeric(wards_2011["WardID"])
```

```
[78]: BRT_attitudes_2011_gdf = wards_2011.merge(BRT_attitudes_2011, on='WardID')

      BRT_attitudes_2011_gdf
```

```
[78]:     OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
      0        600           GT      Gauteng                   JHB         67
      1       4877           GT      Gauteng                   JHB         67
      2        601           GT      Gauteng                   JHB         68
      3       4878           GT      Gauteng                   JHB         68
      4        602           GT      Gauteng                   JHB         69
      ..       ...          ...          ...                   ...        ...
      91      7840           GT      Gauteng                   TSH         81
      92      3574           GT      Gauteng                   TSH         92
      93      7851           GT      Gauteng                   TSH         92
      94      3578           GT      Gauteng                   TSH         96
      95      7855           GT      Gauteng                   TSH         96

            WardID LocalMunicipalityName DistrictMunicipalityCode  \
      0   79800067  City of Johannesburg                      JHB
      1   79800067  City of Johannesburg                      JHB
      2   79800068  City of Johannesburg                      JHB
      3   79800068  City of Johannesburg                      JHB
      4   79800069  City of Johannesburg                      JHB
      ..       ...                   ...                      ...
      91  79900081       City of Tshwane                      TSH
      92  79900092       City of Tshwane                      TSH
      93  79900092       City of Tshwane                      TSH
      94  79900096       City of Tshwane                      TSH
      95  79900096       City of Tshwane                      TSH

         DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
      0      City of Johannesburg  2011  5.822398e+06   14839.026704
      1      City of Johannesburg  2011  5.822398e+06   14839.026704
```

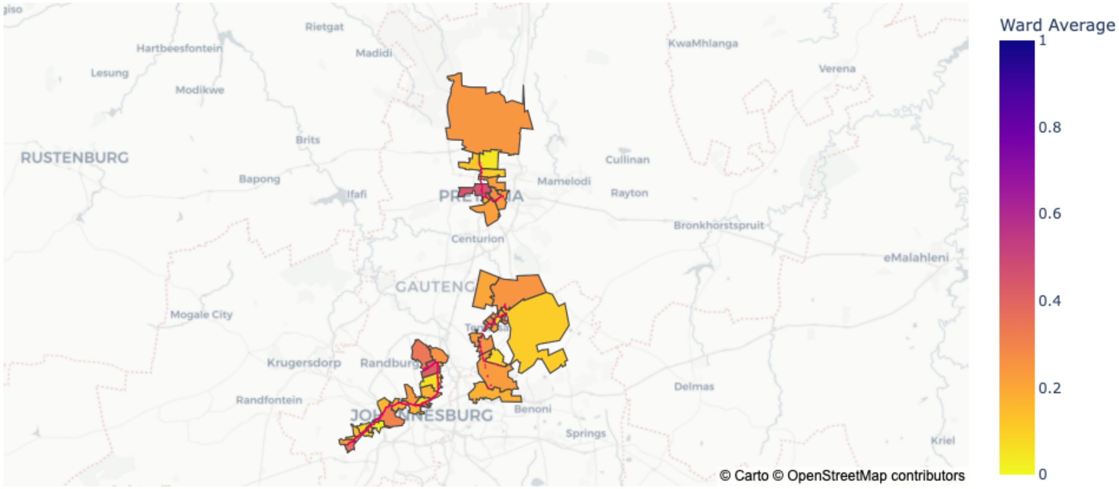
```
2      City of Johannesburg  2011  2.196683e+07   26442.251672
3      City of Johannesburg  2011  2.196683e+07   26442.251672
4      City of Johannesburg  2011  9.416403e+06   17883.257578
..                      …   …            …             …
91          City of Tshwane  2011  1.287117e+06    5579.556212
92          City of Tshwane  2011  6.850188e+06   14113.720798
93          City of Tshwane  2011  6.850188e+06   14113.720798
94          City of Tshwane  2011  3.015758e+08  101853.252738
95          City of Tshwane  2011  3.015758e+08  101853.252738

                                             geometry   BRT Line  \
0   POLYGON ((28.05405 -26.16921, 28.05378 -26.171…   Rea Vaya
1   POLYGON ((28.05405 -26.16921, 28.05378 -26.171…   Rea Vaya
2   POLYGON ((27.97838 -26.19068, 27.97831 -26.191…   Rea Vaya
3   POLYGON ((27.97838 -26.19068, 27.97831 -26.191…   Rea Vaya
4   POLYGON ((27.99591 -26.17295, 27.99494 -26.176…   Rea Vaya
..                                                …          …
91  POLYGON ((28.19874 -25.74177, 28.19905 -25.741…  A Re Yang
92  POLYGON ((28.21090 -25.72931, 28.21094 -25.729…  A Re Yang
93  POLYGON ((28.21090 -25.72931, 28.21094 -25.729…  A Re Yang
94  POLYGON ((28.14057 -25.49034, 28.14042 -25.493…  A Re Yang
95  POLYGON ((28.14057 -25.49034, 28.14042 -25.493…  A Re Yang

    att_foreign_mean  bw_trust_mean
0           0.066667       1.684211
1           0.066667       1.684211
2           0.307692       1.400000
3           0.307692       1.400000
4           0.180000       1.266667
..               …            …
91          0.300000       1.434783
92          0.269231       1.615385
93          0.269231       1.615385
94          0.250000       1.111111
95          0.250000       1.111111

[96 rows x 16 columns]
```

I want to create an interactive map of both attitudes toward foreigners and black and white trust variables to see if there is any change between 2011 and 2017. While we have developed a purple/blue color scheme for our variables, to easily identify any changes, I will be using sequential color schemes for these maps

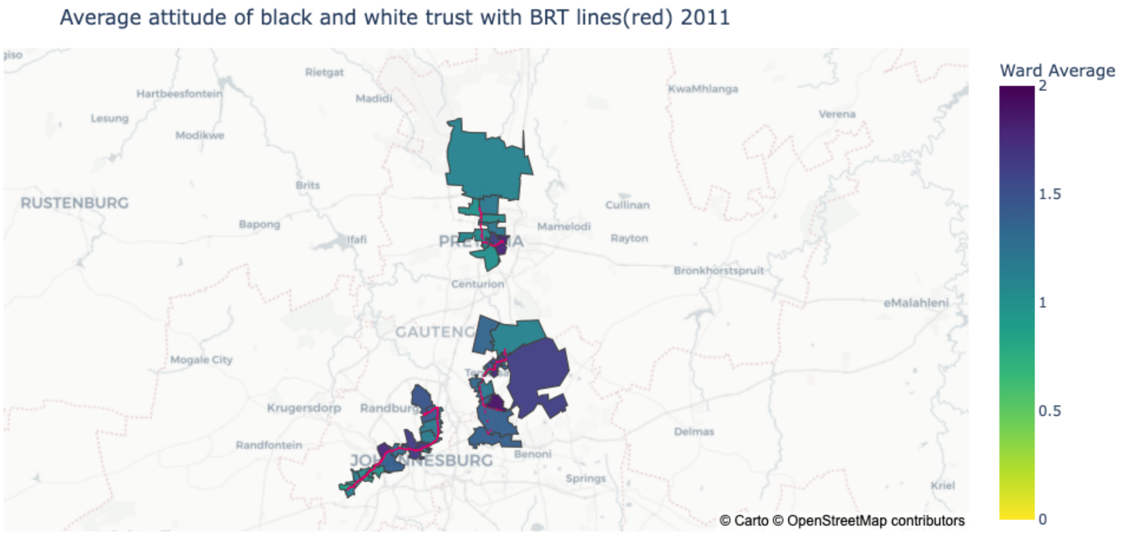
[79]:
```
BRT_attitudes_2011_gdf = BRT_attitudes_2011_gdf.to_crs(epsg=4326) # convert the␣
 ↪coordinate reference system to lat/long
BRT_attitudes_2011_json = BRT_attitudes_2011_gdf.__geo_interface__ #covert to␣
 ↪geoJSON
```

```
[91]: fig = px.choropleth_mapbox(BRT_attitudes_2011_gdf,␣
       ↪geojson=BRT_attitudes_2011_json, locations=BRT_attitudes_2011_gdf.index,␣
       ↪color='att_foreign_mean',
                                 color_continuous_scale="Plasma_r",
                                 range_color=(0, 1),
                                 hover_name= BRT_attitudes_2011_gdf['WardID'],
                                 mapbox_style="carto-positron",
                                 zoom=8, center = {"lat":-25.850187, "lon": 28.
       ↪198042},
                                 opacity=0.9,
                                 title="Average attitude toward foreigners with BRT␣
       ↪lines(red) 2011",
                                 labels={"att_foreign_mean": "Ward Average"}
                                )

      fig.add_scattermapbox(
          lat = lats,
          lon = lons,
          marker_size=2,
          marker_color='rgb(235, 0, 100)'
      )

      fig.update_layout(height=450, margin={"r":0,"t":40,"l":0,"b":0})
      fig.show()
      fig.write_html("BRT att_foreigners_2011.html")
```

Average attitude toward foreigners with BRT lines(red) 2011



```
[81]: fig = px.choropleth_mapbox(BRT_attitudes_2011_gdf,␣
       ↪geojson=BRT_attitudes_2011_json, locations=BRT_attitudes_2011_gdf.index,␣
       ↪color='bw_trust_mean',
                                color_continuous_scale="Viridis_r",
                                range_color=(0, 2),
                                hover_name= BRT_attitudes_2011_gdf['WardID'],
                                mapbox_style="carto-positron",
                                zoom=8, center = {"lat":-25.850187, "lon": 28.
↪198042},
                                opacity=0.8,
                                title="Average attitude of black and white trust␣
↪with BRT lines(red) 2011",
                                labels={"bw_trust_mean": "Ward Average"}
                               )

fig.add_scattermapbox(
    lat = lats,
    lon = lons,
    marker_size=2,
    marker_color='rgb(235, 0, 100)'
)

fig.update_layout(height=450, margin={"r":0,"t":40,"l":0,"b":0})
fig.show()
fig.write_html("BRT bw_trust_2011.html")
```



1.7.2 2017

[82]:
```
wards_2017["WardID"] = pd.to_numeric(wards_2017["WardID"])
```

[83]:
```
BRT_attitudes_2017_gdf = wards_2017.merge(BRT_attitudes_2017, on='WardID')
pd.set_option('display.max_rows',20)
```

```
BRT_attitudes_2017_gdf
```

```
[83]:     OBJECTID ProvinceCode ProvinceName LocalMunicipalityCode WardNumber  \
      0       1533           GT      Gauteng                   EKU         89
      1       2558           GT      Gauteng                   JHB         19
      2       2568           GT      Gauteng                   JHB         29
      3       2569           GT      Gauteng                   JHB         30
      4       2570           GT      Gauteng                   JHB         31
      ..       …          …           …                  …        …
      43      4256           GT      Gauteng                   EKU         14
      44      4258           GT      Gauteng                   EKU         16
      45      4259           GT      Gauteng                   EKU         17
      46      4303           GT      Gauteng                   EKU         92
      47      4311           GT      Gauteng                   EKU        100

            WardID LocalMunicipalityName DistrictMunicipalityCode  \
      0   79700089            Ekurhuleni                      EKU
      1   79800019  City of Johannesburg                      JHB
      2   79800029  City of Johannesburg                      JHB
      3   79800030  City of Johannesburg                      JHB
      4   79800031  City of Johannesburg                      JHB
      ..       …                   …                    …
      43  79700014            Ekurhuleni                      EKU
      44  79700016            Ekurhuleni                      EKU
      45  79700017            Ekurhuleni                      EKU
      46  79700092            Ekurhuleni                      EKU
      47  79700100            Ekurhuleni                      EKU

         DistrictMunicipalityName  Year   Shape__Area  Shape__Length  \
      0                Ekurhuleni  2016  1.657774e+08   65119.929571
      1      City of Johannesburg  2016  4.182003e+06   10549.269035
      2      City of Johannesburg  2016  6.702357e+06   13310.759165
      3      City of Johannesburg  2016  3.185999e+06   10554.740483
      4      City of Johannesburg  2016  2.184496e+06    8753.932909
      ..                      …   …           …             …
      43               Ekurhuleni  2016  2.980619e+06    7936.190115
      44               Ekurhuleni  2016  1.319614e+07   18398.339029
      45               Ekurhuleni  2016  6.727162e+07   44019.922369
      46               Ekurhuleni  2016  2.229463e+07   23000.064387
      47               Ekurhuleni  2016  1.269119e+06    5480.687821

                                                 geometry  att_foreign_mean  \
      0   POLYGON ((28.35238 -25.95460, 28.36680 -25.979…          0.135593
      1   POLYGON ((27.89006 -26.26877, 27.88949 -26.269…          0.092593
      2   POLYGON ((27.95300 -26.21879, 27.95342 -26.218…          0.211538
      3   POLYGON ((27.92039 -26.23825, 27.92045 -26.238…          0.357143
      4   POLYGON ((27.92653 -26.22928, 27.92691 -26.229…          0.196078
..                                                 …             …
43  POLYGON ((28.22457 -26.01760, 28.22458 -26.017…         0.134615
44  POLYGON ((28.26300 -26.08213, 28.25852 -26.091…         0.226415
45  POLYGON ((28.25397 -26.10145, 28.25495 -26.102…         0.129630
46  POLYGON ((28.19249 -26.13945, 28.19259 -26.139…         0.116667
47  POLYGON ((28.24533 -25.99403, 28.24537 -25.994…         0.086022

    bw_trust_mean
0        1.152542
1        1.314815
2        1.423077
3        1.035714
4        1.235294
..            …
43       1.173077
44       1.641509
45       1.555556
46       1.350000
47       1.290323

[48 rows x 15 columns]
```

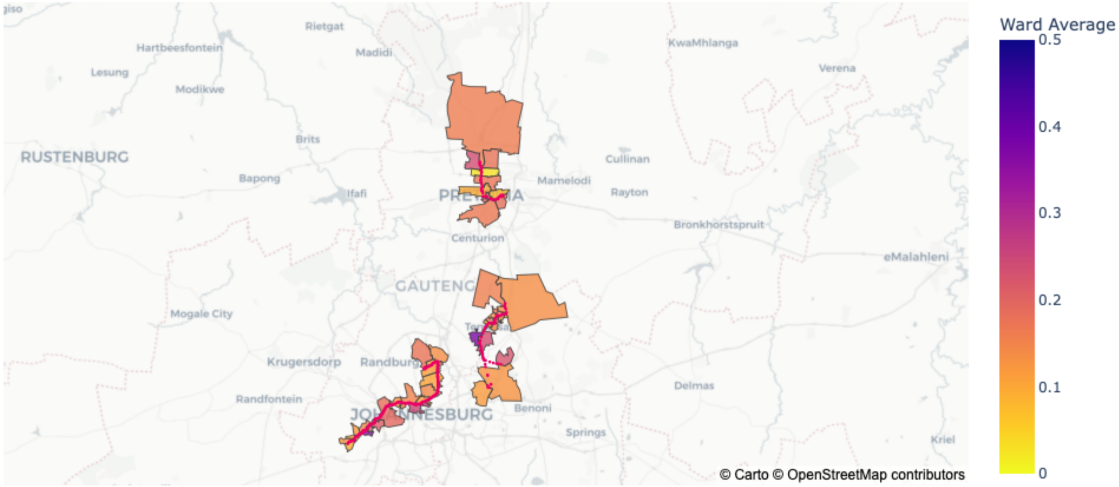
[84]:

```
BRT_attitudes_2017_gdf = BRT_attitudes_2017_gdf.to_crs(epsg=4326) # convert the␣
↪coordinate reference system to lat/long
BRT_attitudes_2017_json = BRT_attitudes_2017_gdf.__geo_interface__ #covert to␣
↪geoJSON
```

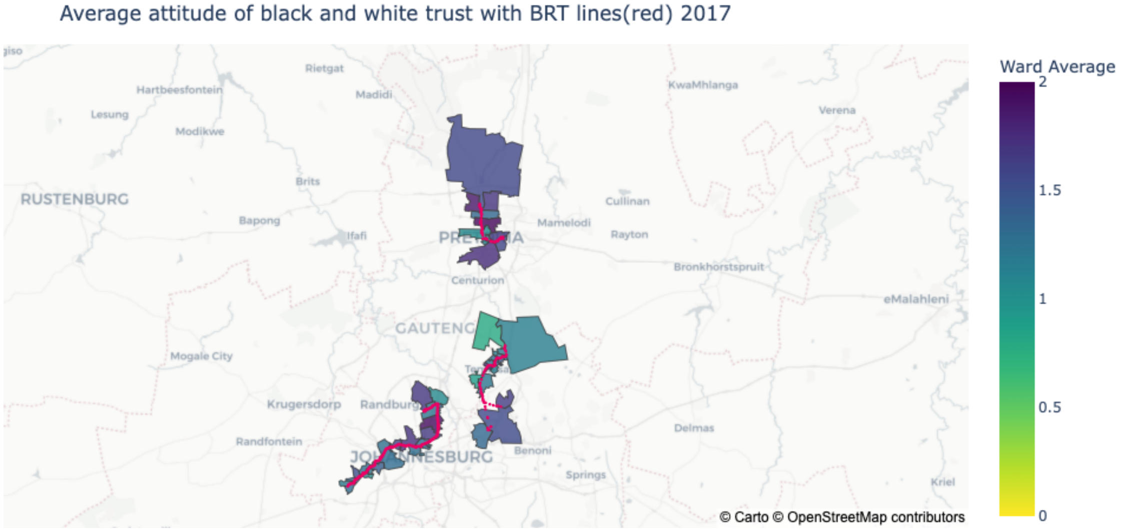
[85]:

```
fig = px.choropleth_mapbox(BRT_attitudes_2017_gdf,␣
↪geojson=BRT_attitudes_2017_json, locations=BRT_attitudes_2017_gdf.index,␣
↪color='att_foreign_mean',
                           color_continuous_scale="Plasma_r",
                           range_color=(0, 0.5),
                           hover_name= BRT_attitudes_2017_gdf['WardID'],
                           mapbox_style="carto-positron",
                           zoom=8, center = {"lat":-25.850187, "lon": 28.
↪198042},
                           opacity=0.8,
                           title="Average attitude toward foreigners with BRT␣
↪lines(red) 2017",
                           labels={"att_foreign_mean": "Ward Average"}
                          )

fig.add_scattermapbox(
    lat = lats,
    lon = lons,
    marker_size=3,
    marker_color='rgb(235, 0, 100)'
)

fig.update_layout(height=450, margin={"r":0,"t":40,"l":0,"b":0})
fig.show()
fig.write_html("BRT att_foreigners_2017.html")
```

Average attitude toward foreigners with BRT lines(red) 2017



[86]:
```
fig = px.choropleth_mapbox(BRT_attitudes_2017_gdf,␣
↪geojson=BRT_attitudes_2017_json, locations=BRT_attitudes_2017_gdf.index,␣
↪color='bw_trust_mean',
                           color_continuous_scale="Viridis_r",
                           range_color=(0, 2),
                           hover_name= BRT_attitudes_2017_gdf['WardID'],
                           mapbox_style="carto-positron",
                           zoom=8, center = {"lat":-25.850187, "lon": 28.
↪198042},
                           opacity=0.8,
                           title="Average attitude of black and white trust␣
↪with BRT lines(red) 2017",
                           labels={"bw_trust_mean": "Ward Average"}
                          )

fig.add_scattermapbox(
    lat = lats,
    lon = lons,
    marker_size=3,
    marker_color='rgb(235, 0, 100)')

fig.update_layout(height=450, margin={"r":0,"t":40,"l":0,"b":0})
fig.show()
fig.write_html("BRT bw_trust_2017.html")
```



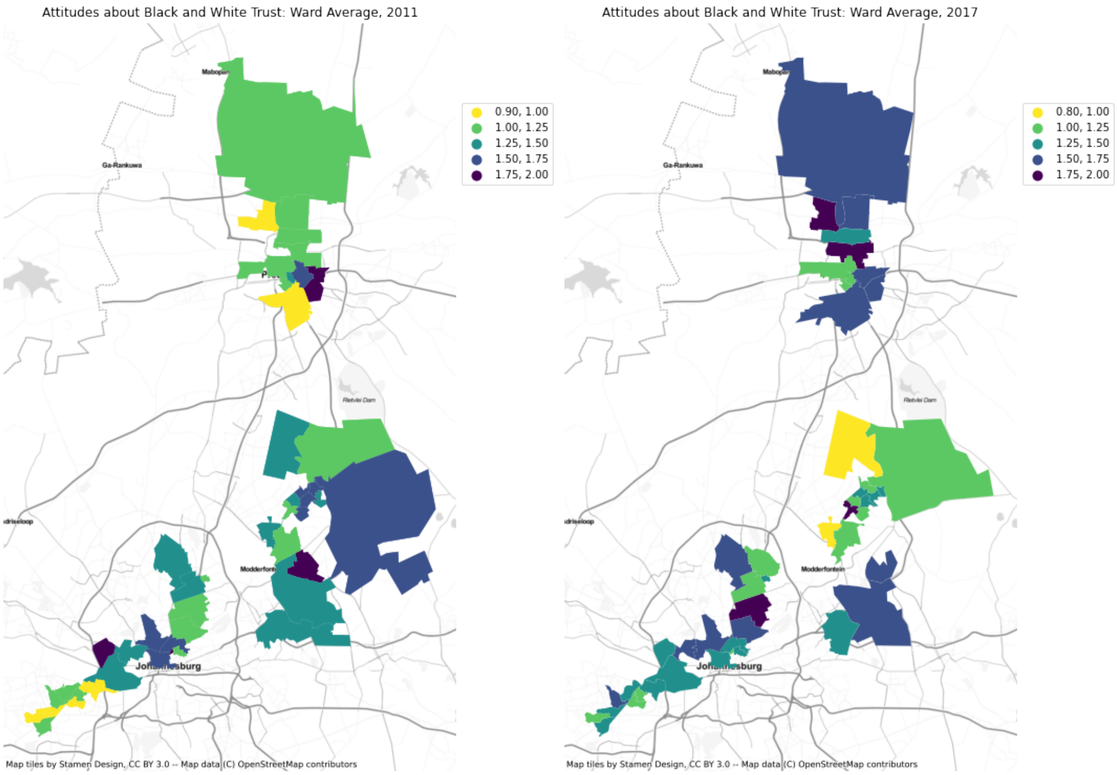
The interactive maps are helpful to see details of each ward, but I'd like to make a side by side static map to easily show any changes

```
[87]: BRT_attitudes_2011_gdf_web_mercator = BRT_attitudes_2011_gdf.to_crs(epsg=3857)
```

```
[88]: BRT_attitudes_2017_gdf_web_mercator = BRT_attitudes_2017_gdf.to_crs(epsg=3857)
```

```
[89]: # create the 1x2 subplots
# set sharex and sharey to true to scale each map equally
fig, axs = plt.subplots(1, 2, figsize=(15, 12), sharex=True, sharey=True)

# name each subplot
ax1, ax2 = axs

# 2011 on the left
base = BRT_attitudes_2011_gdf_web_mercator.plot(column='bw_trust_mean',
                 legend=True,
                 scheme='user_defined',
                     classification_kwds={'bins':[1, 1.25, 1.5, 1.75, 2.0]},
                     legend_kwds={'fmt':'{:.2f}', 'loc':'upper␣
 ↪left','bbox_to_anchor':(1,.9)},
              cmap='viridis_r', edgecolor='white', linewidth=0.05,
                    ax=ax1)

ax1.axis("off")
ax1.set_title('Attitudes about Black and White Trust: Ward Average, 2011')
ctx.add_basemap(ax1,source=ctx.providers.Stamen.TonerLite)
```

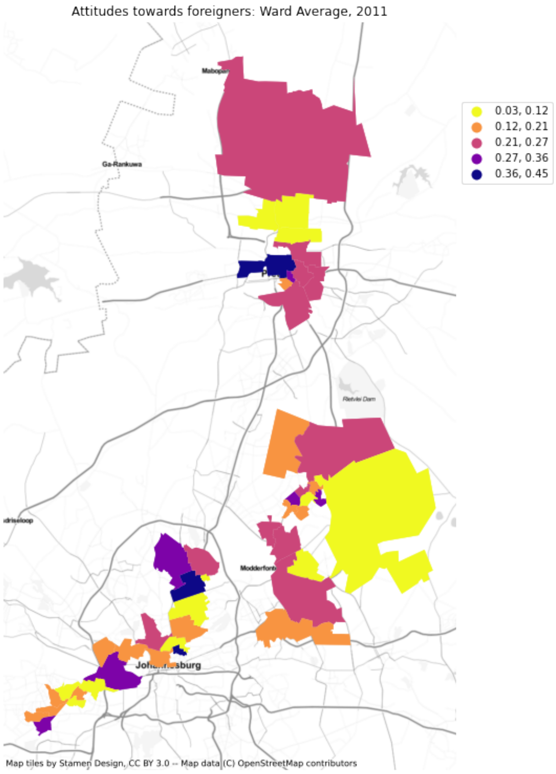
```
# 2017 on the right
base = BRT_attitudes_2017_gdf_web_mercator.plot(column='bw_trust_mean',
                 legend=True,
                 scheme='user_defined',
                     classification_kwds={'bins':[1, 1.25, 1.5, 1.75, 2.0]},
                     legend_kwds={'fmt':'{:.2f}', 'loc':'upper␣
 ↪left','bbox_to_anchor':(1,.9)},
              cmap='viridis_r', edgecolor='white', linewidth=0.05,
                    ax=ax2)

ax2.axis("off")
ax2.set_title('Attitudes about Black and White Trust: Ward Average, 2017')
ctx.add_basemap(ax2,source=ctx.providers.Stamen.TonerLite)
plt.tight_layout()
fig.savefig('bw_trust_2011_2017.png', dpi='figure')
```


Attitudes about Black and White Trust: Ward Average, 2011
Attitudes about Black and White Trust: Ward Average, 2017
0.90, 1.00
1.00, 1.25
1.25, 1.50
1.50, 1.75
1.75, 2.00
0.80, 1.00
1.00, 1.25
1.25, 1.50
1.50, 1.75
1.75, 2.00
Mabopane
Ga-Rankuwa
Rietvlei Dam
Modderfontein
Johannesburg
Map tiles by Stamen Design, CC BY 3.0 -- Map data (C) OpenStreetMap contributors
Map tiles by Stamen Design, CC BY 3.0 -- Map data (C) OpenStreetMap contributors

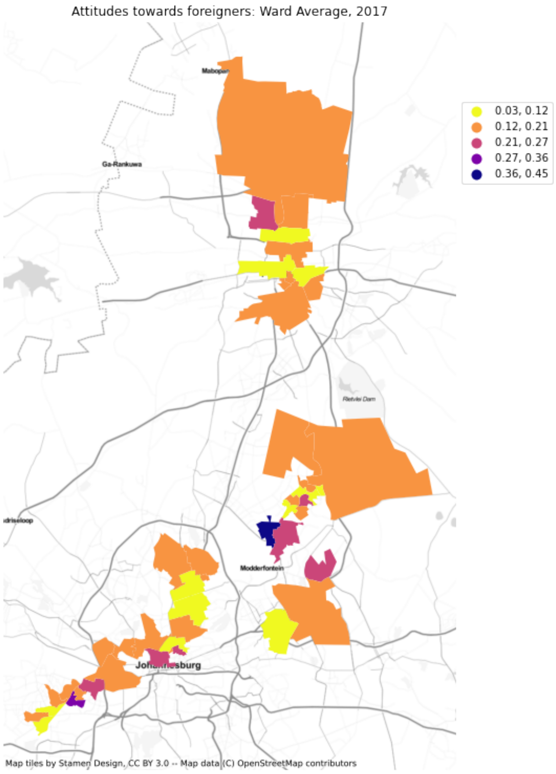
[90]:

```
# create the 1x2 subplots
# set sharex and sharey to true to scale each map equally
fig, axs = plt.subplots(1, 2, figsize=(15, 12), sharex=True, sharey=True)

# name each subplot
```

```
ax1, ax2 = axs

# 2011 on the left
base = BRT_attitudes_2011_gdf_web_mercator.plot(column='att_foreign_mean',
                 legend=True,
                 scheme='natural_breaks',
                    # classification_kwds={'bins':[0.10, 0.20, 0.30, 0.40, 0.
 ↪50]},
                     legend_kwds={'fmt':'{:.2f}', 'loc':'upper␣
 ↪left','bbox_to_anchor':(1,.9)},
              cmap='plasma_r', edgecolor='white', linewidth=0.05,
                    ax=ax1)

ax1.axis("off")
ax1.set_title('Attitudes towards foreigners: Ward Average, 2011')
ctx.add_basemap(ax1,source=ctx.providers.Stamen.TonerLite)

# 2017 on the right
base = BRT_attitudes_2017_gdf_web_mercator.plot(column='att_foreign_mean',
                 legend=True,
                 scheme='user_defined',
                     classification_kwds={'bins':[0.12, 0.21, 0.27, 0.36, 0.
 ↪45]},
                     legend_kwds={'fmt':'{:.2f}', 'loc':'upper␣
 ↪left','bbox_to_anchor':(1,.9)},
              cmap='plasma_r', edgecolor='white', linewidth=0.05,
                    ax=ax2)

ax2.axis("off")
ax2.set_title('Attitudes towards foreigners: Ward Average, 2017')
ctx.add_basemap(ax2,source=ctx.providers.Stamen.TonerLite)
plt.tight_layout()
fig.savefig('attitudes_2011_2017.png', dpi='figure')
```



Map tiles by Stamen Design, CC BY 3.0 -- Map data (C) OpenStreetMap contributors



Map tiles by Stamen Design, CC BY 3.0 -- Map data (C) OpenStreetMap contributors

1.8 Final Thoughts

We can see that there has been a shift in attitudes in both variables, however because we can't control for other conditions, we can't conclusively say BRT has made a significant impact on social attitudes. Additionally, there is still a lot of variation in responses between the wards