Notebook3_Midterm Data Exploration and Analysis-Transit System

February 8, 2021

1 Notebook 3

Project:" Intra-Regional Migration and Transportation in New York Metro Area"

Due to the large data our team is working with, there are a total of four notebooks submitted for this midterm (two from each team member)

I also outlined the notebook into the Table of Content

2 Research Questions

- **In this notebook: What's the transit network look alike in New York Metro Area?**
  - **Expected Exploration:**
    - We expect to combine three transit rail network shapefiles to create a regional transit line map, and we expect to combine three transit station network shapefiles to create a regional transit station map on New York Metro Region.
    - We expect to create an interactive map with the regional transit stations.
  - **Purpose of this notebook:**
    - In this notebook, I first introduced research questions regarding transit network and data sources, and I conducted data explorationa and analysis of transit network in NYMA. I combined and mapped the transit stations and lines of three dominating transit systems, including the New Jersey Rail, Long Island Railroad and Metro-North Railroad. This notebook only covers the initial comining and mapping of the transit network since my teammate and I will conduct analysis to answer the research questions in later weeks during the quarter.
- **We are expecting to analyze and answer the following research questions in the next few weeks after midterm:**
  - **Q1: What's the transit density of each county in the New York Metro Area?**
  - **Q2: Are counties with higher transit density popular migration destinations in the New York Metro Area?**

3 Data source

1. NJ Rail Lines: https://njogis-newjersey.opendata.arcgis.com/datasets/passenger-railroad-lines-in-nj
2. NJ Rail Stations: https://njogis-newjersey.opendata.arcgis.com/datasets/railroad-stations-in-nj
3. LIRR: https://catalog.data.gov/es_AR/dataset/long-island-railroad-map
4. Metro North Lines: https://maps.princeton.edu/catalog/nyu-2451-34755
5. Metro North Stations: https://maps.princeton.edu/catalog/nyu-2451-34756.

4 Importing libraries

[1]:
```
import geopandas as gpd
import matplotlib.pyplot as plt
import plotly.express as px
```

5 Data exploration

5.1 Data exploration for transit lines

[47]:
```
njrail=gpd.read_file('NJRail_line/Passenger_Railroad_Lines_in_NJ.shp')
njstation=gpd.read_file('NJRail_station/Railroad_Stations_in_NJ.shx')
lirail=gpd.read_file('nyu-2451-34753-geojson.json')
listation=gpd.read_file('nyu-2451-34754-geojson.json')
mnrail=gpd.read_file('MNStation/mnline.json')
mnstation=gpd.read_file('MNStation/stops.json')
```

[4]:
```
#looking at first 5 rows of the njrail, lirail and mnrail datasets.
njrail.head()
```

[4]:

	OBJECTID	RAIL_LINE	SERVICE	Shape_Leng	DATE_STAMP	geometry
0	1	ATLANTIC CITY RAIL LINE	None	356957.019400	2016-08-30	LINESTRING (508669.853 193016.598, 505026.387 …
1	2	BERGEN COUNTY LINE	HOBOKEN	155780.575084	2013-11-04	LINESTRING (622908.638 692949.426, 620720.513 …
2	3	MAIN LINE	HOBOKEN	161721.051881	2013-11-04	LINESTRING (587611.064 830753.567, 588462.132 …
3	4	MEADOWLANDS RAIL LINE	None	56328.562168	2013-11-04	LINESTRING (622908.638 692949.426, 620720.513 …
4	5	MONTCLAIR BOONTON LINE	NEW YORK CITY	328910.733006	2013-11-04	LINESTRING (399357.761 735253.132, 399513.899 …

[5]:
```
lirail.head()
```

[5]:
```
                  id  route_id      route_long  \
0  nyu_2451_34753.1        11         Belmont
1  nyu_2451_34753.2        10  Port Jefferson
2  nyu_2451_34753.3        12       City Zone
3  nyu_2451_34753.4         1         Babylon
4  nyu_2451_34753.5         3      Oyster Bay

                                            geometry
0  MULTILINESTRING ((-73.99309 40.75074, -73.9924…
1  MULTILINESTRING ((-73.90300 40.74607, -73.9034…
2  MULTILINESTRING ((-73.80933 40.69955, -73.8100…
3  MULTILINESTRING ((-73.99309 40.75074, -73.9924…
4  MULTILINESTRING ((-73.99309 40.75074, -73.9924…
```

[6]:
```
mnrail.head()
```

[6]:
```
                  id  route_id  route_long  \
0  nyu_2451_34755.1         1      Hudson
1  nyu_2451_34755.2         3   New Haven
2  nyu_2451_34755.3         2      Harlem
3  nyu_2451_34755.4         5     Danbury
4  nyu_2451_34755.5         4  New Canaan

                                            geometry
0  MULTILINESTRING ((-73.93795 41.70584, -73.9472…
1  MULTILINESTRING ((-72.92175 41.30498, -72.9282…
2  MULTILINESTRING ((-73.56220 41.81472, -73.5582…
3  MULTILINESTRING ((-73.45016 41.39636, -73.4181…
4  MULTILINESTRING ((-73.49563 41.14630, -73.4981…
```

As you can see from the first few rows of the three rail line datasets, they all have different columns, however, they all have a few things in common, including the name of each rail line and geometry, but those two columns in the three datasets have different names, so I need to change column names to merge them together into one new dataframe.

[7]:
```
list(njrail)
```

[7]:
```
['OBJECTID', 'RAIL_LINE', 'SERVICE', 'Shape_Leng', 'DATE_STAMP', 'geometry']
```

[8]:
```
njrail.columns=['id','linename','service','shape_leng','date_stamp','geometry']
njrail.head()
```

[8]:
```
   id                 linename        service     shape_leng  date_stamp  \
0   1  ATLANTIC CITY RAIL LINE           None  356957.019400  2016-08-30
1   2       BERGEN COUNTY LINE       HOBOKEN  155780.575084  2013-11-04
2   3                MAIN LINE       HOBOKEN  161721.051881  2013-11-04
3   4    MEADOWLANDS RAIL LINE           None   56328.562168  2013-11-04
```

```
4   5   MONTCLAIR BOONTON LINE  NEW YORK CITY  328910.733006  2013-11-04

                                                 geometry
0  LINESTRING (508669.853 193016.598, 505026.387 …
1  LINESTRING (622908.638 692949.426, 620720.513 …
2  LINESTRING (587611.064 830753.567, 588462.132 …
3  LINESTRING (622908.638 692949.426, 620720.513 …
4  LINESTRING (399357.761 735253.132, 399513.899 …
```

[9]:
```
#Let's add a new column called "operating" to the mnrail dataframe to␣
 ↪distinguish it from two other rail line dataframes.
njrail['Operating'] = 'New Jersey Railroad'
njrail.head()
```

[9]:
```
   id                 linename        service     shape_leng  date_stamp  \
0   1  ATLANTIC CITY RAIL LINE           None  356957.019400  2016-08-30
1   2       BERGEN COUNTY LINE        HOBOKEN  155780.575084  2013-11-04
2   3                MAIN LINE        HOBOKEN  161721.051881  2013-11-04
3   4    MEADOWLANDS RAIL LINE           None   56328.562168  2013-11-04
4   5   MONTCLAIR BOONTON LINE  NEW YORK CITY  328910.733006  2013-11-04

                                                 geometry            Operating
0  LINESTRING (508669.853 193016.598, 505026.387 …  New Jersey Railroad
1  LINESTRING (622908.638 692949.426, 620720.513 …  New Jersey Railroad
2  LINESTRING (587611.064 830753.567, 588462.132 …  New Jersey Railroad
3  LINESTRING (622908.638 692949.426, 620720.513 …  New Jersey Railroad
4  LINESTRING (399357.761 735253.132, 399513.899 …  New Jersey Railroad
```

[10]:
```
list(lirail)
```

[10]:
```
['id', 'route_id', 'route_long', 'geometry']
```

[11]:
```
lirail.columns=['id','number','linename','geometry']
lirail.head()
```

[11]:
```
                id  number        linename  \
0  nyu_2451_34753.1      11         Belmont
1  nyu_2451_34753.2      10  Port Jefferson
2  nyu_2451_34753.3      12       City Zone
3  nyu_2451_34753.4       1         Babylon
4  nyu_2451_34753.5       3      Oyster Bay

                                                 geometry
0  MULTILINESTRING ((-73.99309 40.75074, -73.9924…
1  MULTILINESTRING ((-73.90300 40.74607, -73.9034…
2  MULTILINESTRING ((-73.80933 40.69955, -73.8100…
3  MULTILINESTRING ((-73.99309 40.75074, -73.9924…
```

```
4  MULTILINESTRING ((-73.99309 40.75074, -73.9924…
```

[12]:
```
#Let's add a new column called "operating" to the mnrail dataframe to␣
↪distinguish it from two other rail line dataframes.
lirail['Operating'] = 'Long Island Railroad'
lirail.head()
```

[12]:
```
                 id  number        linename  \
0  nyu_2451_34753.1      11         Belmont
1  nyu_2451_34753.2      10  Port Jefferson
2  nyu_2451_34753.3      12       City Zone
3  nyu_2451_34753.4       1         Babylon
4  nyu_2451_34753.5       3      Oyster Bay

                                            geometry             Operating
0  MULTILINESTRING ((-73.99309 40.75074, -73.9924…  Long Island Railroad
1  MULTILINESTRING ((-73.90300 40.74607, -73.9034…  Long Island Railroad
2  MULTILINESTRING ((-73.80933 40.69955, -73.8100…  Long Island Railroad
3  MULTILINESTRING ((-73.99309 40.75074, -73.9924…  Long Island Railroad
4  MULTILINESTRING ((-73.99309 40.75074, -73.9924…  Long Island Railroad
```

[13]:
```
list(mnrail)
```

[13]:
```
['id', 'route_id', 'route_long', 'geometry']
```

[14]:
```
mnrail.columns=['id','number','linename','geometry']
mnrail.head()
```

[14]:
```
                 id  number    linename  \
0  nyu_2451_34755.1       1      Hudson
1  nyu_2451_34755.2       3   New Haven
2  nyu_2451_34755.3       2      Harlem
3  nyu_2451_34755.4       5     Danbury
4  nyu_2451_34755.5       4  New Canaan

                                            geometry
0  MULTILINESTRING ((-73.93795 41.70584, -73.9472…
1  MULTILINESTRING ((-72.92175 41.30498, -72.9282…
2  MULTILINESTRING ((-73.56220 41.81472, -73.5582…
3  MULTILINESTRING ((-73.45016 41.39636, -73.4181…
4  MULTILINESTRING ((-73.49563 41.14630, -73.4981…
```

Now we have changed the names of shared columns (names and geometry) in three dataframe to the same names.

I also noticed that in the geometry columns of the three transit line datasets that they do not use the same geometry coordination system, so I'm going to change them to share the same coordination system.

[15]:
```
lirail=lirail.to_crs('epsg:3424')
lirail.head()
```

[15]:

	id	number	linename	geometry	Operating
0	nyu_2451_34753.1	11	Belmont	MULTILINESTRING ((632561.894 698796.549, 63274…	Long Island Railroad
1	nyu_2451_34753.2	10	Port Jefferson	MULTILINESTRING ((657530.427 697249.579, 65739…	Long Island Railroad
2	nyu_2451_34753.3	12	City Zone	MULTILINESTRING ((683616.747 680493.214, 68342…	Long Island Railroad
3	nyu_2451_34753.4	1	Babylon	MULTILINESTRING ((632561.894 698796.549, 63274…	Long Island Railroad
4	nyu_2451_34753.5	3	Oyster Bay	MULTILINESTRING ((632561.894 698796.549, 63274…	Long Island Railroad

[16]:
```
mnrail=mnrail.to_crs('epsg:3424')
mnrail.head()
```

[16]:

	id	number	linename	geometry
0	nyu_2451_34755.1	1	Hudson	MULTILINESTRING ((645588.804 1046859.351, 6433…
1	nyu_2451_34755.2	3	New Haven	MULTILINESTRING ((925725.242 904249.608, 92398…
2	nyu_2451_34755.3	2	Harlem	MULTILINESTRING ((747752.029 1087426.164, 7489…
3	nyu_2451_34755.4	5	Danbury	MULTILINESTRING ((780145.485 935346.610, 78901…
4	nyu_2451_34755.5	4	New Canaan	MULTILINESTRING ((768726.204 844093.227, 76815…

[17]:
```
#Let's add a new column called "operating" to the mnrail dataframe to␣
↪distinguish it from two other rail line dataframes.
mnrail['Operating'] = 'Metro North'
mnrail.head()
```

[17]:

	id	number	linename	geometry	Operating
0	nyu_2451_34755.1	1	Hudson	MULTILINESTRING ((645588.804 1046859.351, 6433…	Metro North
1	nyu_2451_34755.2	3	New Haven	MULTILINESTRING ((925725.242 904249.608, 92398…	Metro North
2	nyu_2451_34755.3	2	Harlem	MULTILINESTRING ((747752.029 1087426.164, 7489…	Metro North
3	nyu_2451_34755.4	5	Danbury	MULTILINESTRING ((780145.485 935346.610, 78901…	Metro North
4	nyu_2451_34755.5	4	New Canaan	MULTILINESTRING ((768726.204 844093.227, 76815…	Metro North

```
0  MULTILINESTRING ((645588.804 1046859.351, 6433…  Metro North
1  MULTILINESTRING ((925725.242 904249.608, 92398…  Metro North
2  MULTILINESTRING ((747752.029 1087426.164, 7489…  Metro North
3  MULTILINESTRING ((780145.485 935346.610, 78901…  Metro North
4  MULTILINESTRING ((768726.204 844093.227, 76815…  Metro North
```

Now the geometry columns of the three dataframes share the same coordination system, and we can merge them into one dataframe now. But before we do that, let's just look at the data types of the three dataframes.

[18]:
```
#check datatypes of columns
njrail.dtypes
```

[18]:
```
id               int64
linename        object
service         object
shape_leng     float64
date_stamp      object
geometry      geometry
Operating       object
dtype: object
```

[19]:
```
lirail.dtypes
```

[19]:
```
id             object
number          int64
linename       object
geometry     geometry
Operating      object
dtype: object
```

[20]:
```
mnrail.dtypes
```

[20]:
```
id             object
number          int64
linename       object
geometry     geometry
Operating      object
dtype: object
```

Let's combine the three rail line dataframe into a new one.

[21]:
```
linjrail = lirail.append(njrail)
nymarail=linjrail.append(mnrail)
```

[22]:
```
#Let's sample the new datagframe with the combined rail lines to make sure␣
 ↪there are values from all three dataframes.
nymarail.sample(10)
```

[22]:
```
                  id  number                  linename  \
8                  9     NaN            MORRIS & ESSEX
20                21     NaN                RIVER LINE
4   nyu_2451_34753.5     3.0                Oyster Bay
29                30     NaN                     SEPTA
17                18     NaN          PORT JERVIS LINE
6                  7     NaN            MORRIS & ESSEX
0                  1     NaN   ATLANTIC CITY RAIL LINE
21                22     NaN  HUDSON BERGEN LIGHT RAIL
5   nyu_2451_34753.6     2.0                 Hempstead
2                  3     NaN                 MAIN LINE

                                             geometry             Operating  \
8   LINESTRING (446012.803 687337.456, 446094.132 …   New Jersey Railroad
20  LINESTRING (316095.939 403450.376, 316096.891 …   New Jersey Railroad
4   MULTILINESTRING ((632561.894 698796.549, 63274…  Long Island Railroad
29  LINESTRING (301113.611 409819.346, 301275.538 …   New Jersey Railroad
17  LINESTRING (622908.638 692949.426, 620720.513 …   New Jersey Railroad
6   LINESTRING (446012.803 687337.456, 446094.132 …   New Jersey Railroad
0   LINESTRING (508669.853 193016.598, 505026.387 …   New Jersey Railroad
21  MULTILINESTRING ((614528.455 683433.565, 61438…   New Jersey Railroad
5   MULTILINESTRING ((632561.894 698796.549, 63274…  Long Island Railroad
2   LINESTRING (587611.064 830753.567, 588462.132 …   New Jersey Railroad

                              service     shape_leng  date_stamp
8   MIDTOWN DIRECT VIA GLADSTONE LINE  237101.943694  2013-11-04
20                                None  178427.379126  2014-06-27
4                                  NaN            NaN         NaN
29                  WEST TRENTON LINE  179332.779356  2016-08-30
17             VIA BERGEN COUNTY LINE  508072.868956  2013-11-04
6               HOBOKEN VIA GLADSTONE  223151.889045  2013-11-04
0                                 None  356957.019400  2016-08-30
21                                None   84752.100389  2014-06-27
5                                  NaN            NaN         NaN
2                              HOBOKEN  161721.051881  2013-11-04
```

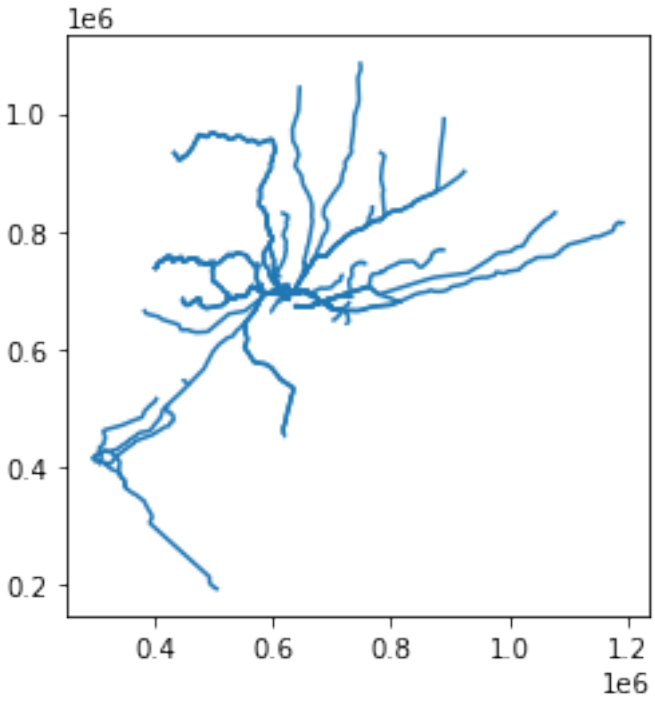
[23]:
```
#Let's clean up the data a little more and get rid of the columns where there␣
 ↪are some rows without value.
columns_to_keep=['linename','geometry','Operating']
nymarail=nymarail[columns_to_keep]
nymarail.sample(10)
```

[23]:
```
                 linename                                           geometry  \
2                  Harlem  MULTILINESTRING ((747752.029 1087426.164, 7489…
6           MORRIS & ESSEX  LINESTRING (446012.803 687337.456, 446094.132 …
1           Port Jefferson  MULTILINESTRING ((657530.427 697249.579, 65739…
4   MONTCLAIR BOONTON LINE  LINESTRING (399357.761 735253.132, 399513.899 …
```

```
8           MORRIS & ESSEX  LINESTRING (446012.803 687337.456, 446094.132 …
3    MEADOWLANDS RAIL LINE  LINESTRING (622908.638 692949.426, 620720.513 …
11          West Hempstead  MULTILINESTRING ((683681.521 680482.988, 68361…
4               Oyster Bay  MULTILINESTRING ((632561.894 698796.549, 63274…
19                   SEPTA  LINESTRING (421410.675 504820.167, 421246.279 …
28                    PATH  MULTILINESTRING ((621068.883 690997.491, 62107…

                Operating
2            Metro North
6     New Jersey Railroad
1    Long Island Railroad
4     New Jersey Railroad
8     New Jersey Railroad
3     New Jersey Railroad
11   Long Island Railroad
4    Long Island Railroad
19    New Jersey Railroad
28    New Jersey Railroad
```

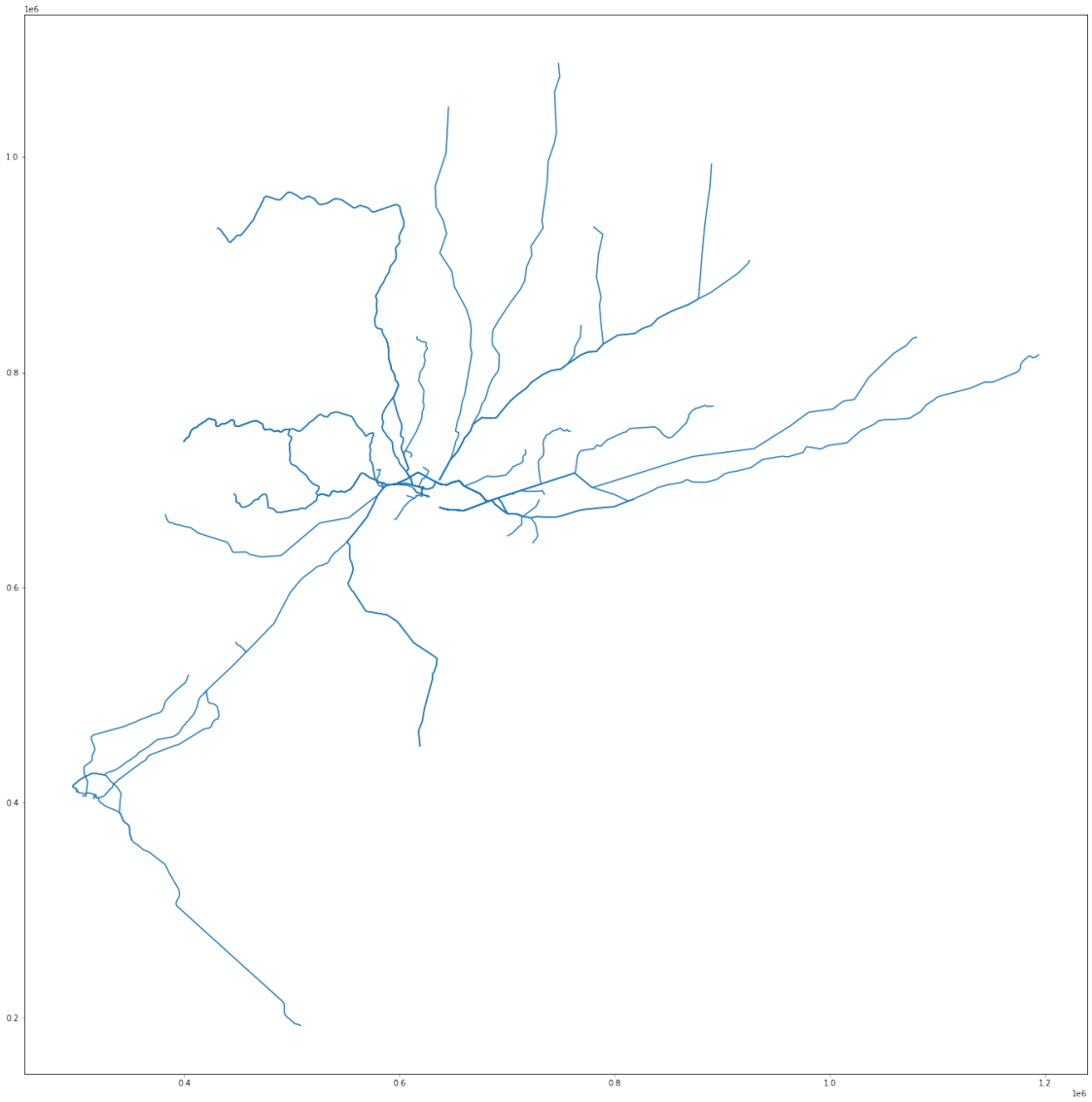
[24]:
```
#Let's plot the combined rail lines onto the map
nymarail.plot()
```

[24]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f22c97e6ac0>
```



[25]:
```
#Let's make it look better
nymarail.plot(figsize=(40,24))
```

[25]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f22c98969a0>
```



5.2 Data exploration for transit stations

Let's do the same thing with the station datasets.

[48]:
```
#looking at first 5 rows of the njstation, listation and mnstation datasets.
njstation.head()
```

[48]:
```
   OBJECTID    COUNTY   LATITUDE  LONGITUDE         STATION  \
0         1     OCEAN  40.092718 -74.048192  Point Pleasant
1         2  MONMOUTH  40.150567 -74.035460     Spring Lake
2         3  MONMOUTH  40.180589 -74.027296          Belmar
3         4  MONMOUTH  40.203775 -74.018956   Bradley Beach
4         5  MONMOUTH  40.215360 -74.014788     Asbury Park

                 RAIL_LINE                      MUN_LABEL   ATIS_ID AMTRAK  \
0  North Jersey Coast Line  Point Pleasant Beach Borough  RAIL0122      N
1  North Jersey Coast Line            Spring Lake Borough  RAIL0141      N
2  North Jersey Coast Line                 Belmar Borough  RAIL0015      N
3  North Jersey Coast Line          Bradley Beach Borough  RAIL0022      N
4  North Jersey Coast Line               Asbury Park City  RAIL0008      N

                        geometry
0  POINT (618521.134 459008.903)
1  POINT (621972.996 480099.144)
2  POINT (624196.751 491047.221)
3  POINT (626480.961 499505.650)
4  POINT (627622.290 503731.988)
```

[49]:
```
listation.head()
```

[49]:
```
                 id  stop_id            stop_name  stop_lat  stop_lon  geoid  \
0  nyu_2451_34754.1        1     Long Island City  40.74128 -73.95639  36081
1  nyu_2451_34754.2        2  Hunterspoint Avenue  40.74238 -73.94679  36081
2  nyu_2451_34754.3        8         Penn Station  40.75058 -73.99358  36061
3  nyu_2451_34754.4        9             Woodside  40.74584 -73.90297  36081
4  nyu_2451_34754.5       10         Forest Hills  40.71957 -73.84481  36081

          namelsad                     geometry
0    Queens County  POINT (-73.95639 40.74128)
1    Queens County  POINT (-73.94679 40.74238)
2  New York County  POINT (-73.99358 40.75058)
3    Queens County  POINT (-73.90297 40.74584)
4    Queens County  POINT (-73.84481 40.71957)
```

There are 277 stations in the NJ Rail network and some has multiple values, meaning there are more than 1 lines intersecting at those staions.

[50]:
```
mnstation.head()
```

[50]:
```
                 id  stop_id           stop_name   stop_lat   stop_lon  \
0  nyu_2451_34756.1        1       Grand Central  40.752998 -73.977056
1  nyu_2451_34756.2        4    Harlem-125th St.  40.805157 -73.939149
2  nyu_2451_34756.3      622    Yankees-E153 St.  40.825300 -73.929900
3  nyu_2451_34756.4        9      Morris Heights  40.854252 -73.919583
```

```
4  nyu_2451_34756.5       10  University Heights  40.862248 -73.913120
```

```
   wheelchair  geoid         namelsad                     geometry
0           1  36061  New York County  POINT (-73.97706 40.75300)
1           1  36061  New York County  POINT (-73.93915 40.80516)
2           1  36005     Bronx County  POINT (-73.92990 40.82530)
3           1  36005     Bronx County  POINT (-73.91958 40.85425)
4           1  36005     Bronx County  POINT (-73.91312 40.86225)
```

Again, three dataframes share the names and the geometry columns, and let's change the names of those two columns. From the data exploration and analysis for the rail line dataframes, I know I don't need to keep all the columns as well, so I will drop the columns that are not shared across the dataframes.

[51]:
```
list(njstation)
```

[51]:
```
['OBJECTID',
 'COUNTY',
 'LATITUDE',
 'LONGITUDE',
 'STATION',
 'RAIL_LINE',
 'MUN_LABEL',
 'ATIS_ID',
 'AMTRAK',
 'geometry']
```

[52]:
```
columns_to_keep=['STATION','LATITUDE','LONGITUDE','geometry']
njstation=njstation[columns_to_keep]
njstation.head()
```

[52]:
```
          STATION   LATITUDE  LONGITUDE                       geometry
0  Point Pleasant  40.092718 -74.048192  POINT (618521.134 459008.903)
1     Spring Lake  40.150567 -74.035460  POINT (621972.996 480099.144)
2          Belmar  40.180589 -74.027296  POINT (624196.751 491047.221)
3   Bradley Beach  40.203775 -74.018956  POINT (626480.961 499505.650)
4     Asbury Park  40.215360 -74.014788  POINT (627622.290 503731.988)
```

[53]:
```
njstation.columns=['stationname','lat','lon','geometry']
njstation
```

[53]:
```
        stationname        lat        lon                       geometry
0    Point Pleasant  40.092718 -74.048192  POINT (618521.134 459008.903)
1       Spring Lake  40.150567 -74.035460  POINT (621972.996 480099.144)
2            Belmar  40.180589 -74.027296  POINT (624196.751 491047.221)
3     Bradley Beach  40.203775 -74.018956  POINT (626480.961 499505.650)
4       Asbury Park  40.215360 -74.014788  POINT (627622.290 503731.988)
```

```
..              …        …        …                                  …
280         Bristol  40.105037 -74.854642  POINT (392929.771 463373.005)
281         Croydon  40.093575 -74.906575  POINT (378384.438 459260.172)
282       Eddington  40.082994 -74.933703  POINT (370776.718 455441.562)
283          Tacony  40.023226 -75.039024  POINT (341176.327 433831.875)
284       Levittown  40.140259 -74.817016  POINT (403499.492 476163.107)

[285 rows x 4 columns]
```

[54]:
```
njstation['Operating'] = 'New Jersey Railroad'
njstation.head()
```

[54]:
```
      stationname        lat        lon                        geometry  \
0  Point Pleasant  40.092718 -74.048192  POINT (618521.134 459008.903)
1     Spring Lake  40.150567 -74.035460  POINT (621972.996 480099.144)
2          Belmar  40.180589 -74.027296  POINT (624196.751 491047.221)
3   Bradley Beach  40.203775 -74.018956  POINT (626480.961 499505.650)
4     Asbury Park  40.215360 -74.014788  POINT (627622.290 503731.988)

             Operating
0  New Jersey Railroad
1  New Jersey Railroad
2  New Jersey Railroad
3  New Jersey Railroad
4  New Jersey Railroad
```

[55]:
```
list(listation)
```

[55]:
```
['id',
 'stop_id',
 'stop_name',
 'stop_lat',
 'stop_lon',
 'geoid',
 'namelsad',
 'geometry']
```

[56]:
```
columns_to_keep=['stop_name','stop_lat','stop_lon','geometry']
listation=listation[columns_to_keep]
listation.head()
```

[56]:
```
             stop_name  stop_lat  stop_lon                    geometry
0    Long Island City  40.74128 -73.95639  POINT (-73.95639 40.74128)
1  Hunterspoint Avenue  40.74238 -73.94679  POINT (-73.94679 40.74238)
2        Penn Station  40.75058 -73.99358  POINT (-73.99358 40.75058)
3            Woodside  40.74584 -73.90297  POINT (-73.90297 40.74584)
4        Forest Hills  40.71957 -73.84481  POINT (-73.84481 40.71957)
```

[57]:
```
listation.columns=['stationname','lat','lon','geometry']
listation.head()
```

[57]:

	stationname	lat	lon	geometry
0	Long Island City	40.74128	-73.95639	POINT (-73.95639 40.74128)
1	Hunterspoint Avenue	40.74238	-73.94679	POINT (-73.94679 40.74238)
2	Penn Station	40.75058	-73.99358	POINT (-73.99358 40.75058)
3	Woodside	40.74584	-73.90297	POINT (-73.90297 40.74584)
4	Forest Hills	40.71957	-73.84481	POINT (-73.84481 40.71957)

[58]:
```
listation['Operating'] = 'Long Island Railroad'
listation.head()
```

[58]:

	stationname	lat	lon	geometry	Operating
0	Long Island City	40.74128	-73.95639	POINT (-73.95639 40.74128)	Long Island Railroad
1	Hunterspoint Avenue	40.74238	-73.94679	POINT (-73.94679 40.74238)	Long Island Railroad
2	Penn Station	40.75058	-73.99358	POINT (-73.99358 40.75058)	Long Island Railroad
3	Woodside	40.74584	-73.90297	POINT (-73.90297 40.74584)	Long Island Railroad
4	Forest Hills	40.71957	-73.84481	POINT (-73.84481 40.71957)	Long Island Railroad

[59]:
```
columns_to_keep=['stop_name','stop_lat','stop_lon','geometry']
mnstation=mnstation[columns_to_keep]
mnstation.head()
```

[59]:

	stop_name	stop_lat	stop_lon	geometry
0	Grand Central	40.752998	-73.977056	POINT (-73.97706 40.75300)
1	Harlem-125th St.	40.805157	-73.939149	POINT (-73.93915 40.80516)
2	Yankees-E153 St.	40.825300	-73.929900	POINT (-73.92990 40.82530)
3	Morris Heights	40.854252	-73.919583	POINT (-73.91958 40.85425)
4	University Heights	40.862248	-73.913120	POINT (-73.91312 40.86225)

[60]:
```
mnstation.columns=['stationname','lat','lon','geometry']
mnstation.head()
```

[60]:

	stationname	lat	lon	geometry
0	Grand Central	40.752998	-73.977056	POINT (-73.97706 40.75300)
1	Harlem-125th St.	40.805157	-73.939149	POINT (-73.93915 40.80516)
2	Yankees-E153 St.	40.825300	-73.929900	POINT (-73.92990 40.82530)
3	Morris Heights	40.854252	-73.919583	POINT (-73.91958 40.85425)
4	University Heights	40.862248	-73.913120	POINT (-73.91312 40.86225)

[61]:
```
mnstation['Operating'] = 'Metro North Railroad'
mnstation.head()
```

[61]:

	stationname	lat	lon	geometry	Operating
0	Grand Central	40.752998	-73.977056	POINT (-73.97706 40.75300)	Metro North Railroad
1	Harlem-125th St.	40.805157	-73.939149	POINT (-73.93915 40.80516)	Metro North Railroad
2	Yankees-E153 St.	40.825300	-73.929900	POINT (-73.92990 40.82530)	Metro North Railroad
3	Morris Heights	40.854252	-73.919583	POINT (-73.91958 40.85425)	Metro North Railroad
4	University Heights	40.862248	-73.913120	POINT (-73.91312 40.86225)	Metro North Railroad

Now we have changed the column names for station and geometry to the same across the three dataframes, but I noticed that the coordination system for geometry columns are different, I need to change them to the same coordination system for mapping purpose

[62]:
```
listation=listation.to_crs('epsg:3424')
listation.head()
```

[62]:

	stationname	lat	lon	geometry	Operating
0	Long Island City	40.74128	-73.95639	POINT (642750.072 695409.903)	Long Island Railroad
1	Hunterspoint Avenue	40.74238	-73.94679	POINT (645407.555 695827.249)	Long Island Railroad
2	Penn Station	40.75058	-73.99358	POINT (632425.769 698736.255)	Long Island Railroad
3	Woodside	40.74584	-73.90297	POINT (657540.623 697167.271)	Long Island Railroad
4	Forest Hills	40.71957	-73.84481	POINT (673726.190 687712.061)	Long Island Railroad

[63]:
```
mnstation=mnstation.to_crs('epsg:3424')
mnstation.head()
```

[63]:

	stationname	lat	lon	geometry	Operating
0	Grand Central	40.752998	-73.977056	POINT (636998.419 699643.976)	Metro North Railroad
1	Harlem-125th St.	40.805157	-73.939149	POINT (647378.517 718710.419)	Metro North Railroad
2	Yankees-E153 St.	40.825300	-73.929900	POINT (649891.090 726065.105)	Metro North Railroad
3	Morris Heights	40.854252	-73.919583	POINT (652676.295 736631.220)	Metro North Railroad
4	University Heights	40.862248	-73.913120	POINT (654444.539 739556.129)	Metro North Railroad

```
              Operating
0  Metro North Railroad
1  Metro North Railroad
2  Metro North Railroad
3  Metro North Railroad
4  Metro North Railroad
```

Time to combine the three dataframes.

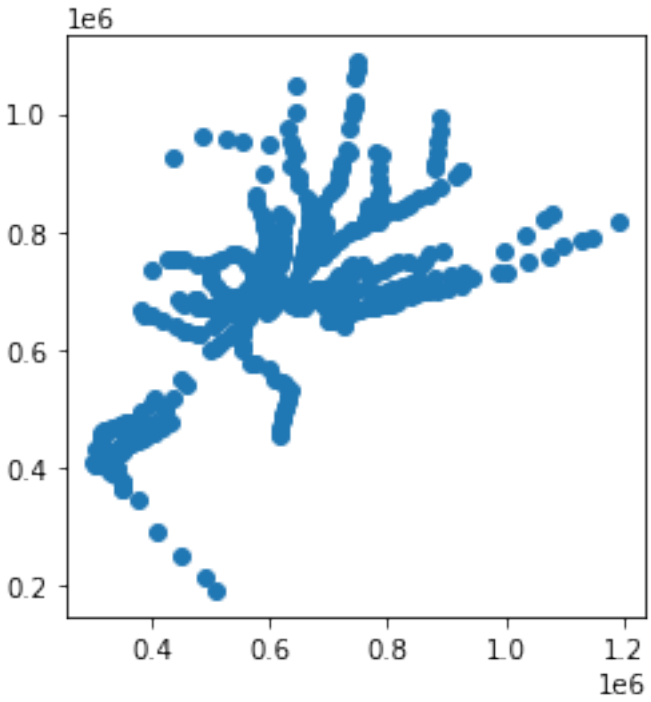
[64]:
```
linjstation= listation.append(njstation)
nymastation=linjstation.append(mnstation)
nymastation.sample(10)
```

[64]:
```
             stationname        lat        lon                          geometry  \
186  Liberty State Park  40.710375 -74.055813   POINT (615258.507 683996.307)
195         E. 22nd St.  40.661304 -74.116456   POINT (598525.575 666040.662)
27         North Branch  40.592027 -74.683792   POINT (441085.674 640625.347)
90             Bay Head  40.077189 -74.046181   POINT (619112.507 453355.211)
93              Danbury  41.396363 -73.450163   POINT (780145.485 935346.610)
2      Yankees-E153 St.  40.825300 -73.929900   POINT (649891.090 726065.105)
63          Mount Olive  40.907384 -74.730645   POINT (428376.443 755539.676)
120       Bridgehampton  40.938980 -72.310050  POINT (1097142.363 774544.545)
121        East Hampton  40.965080 -72.193240  POINT (1129164.812 784884.410)
16           Douglaston  40.768060 -73.749410   POINT (700017.690 705588.664)

                Operating
186   New Jersey Railroad
195   New Jersey Railroad
27    New Jersey Railroad
90    New Jersey Railroad
93   Metro North Railroad
2    Metro North Railroad
63    New Jersey Railroad
120  Long Island Railroad
121  Long Island Railroad
16   Long Island Railroad
```

Time to plot the combined station dataframe onto the map

[65]:
```
nymastation.plot()
```

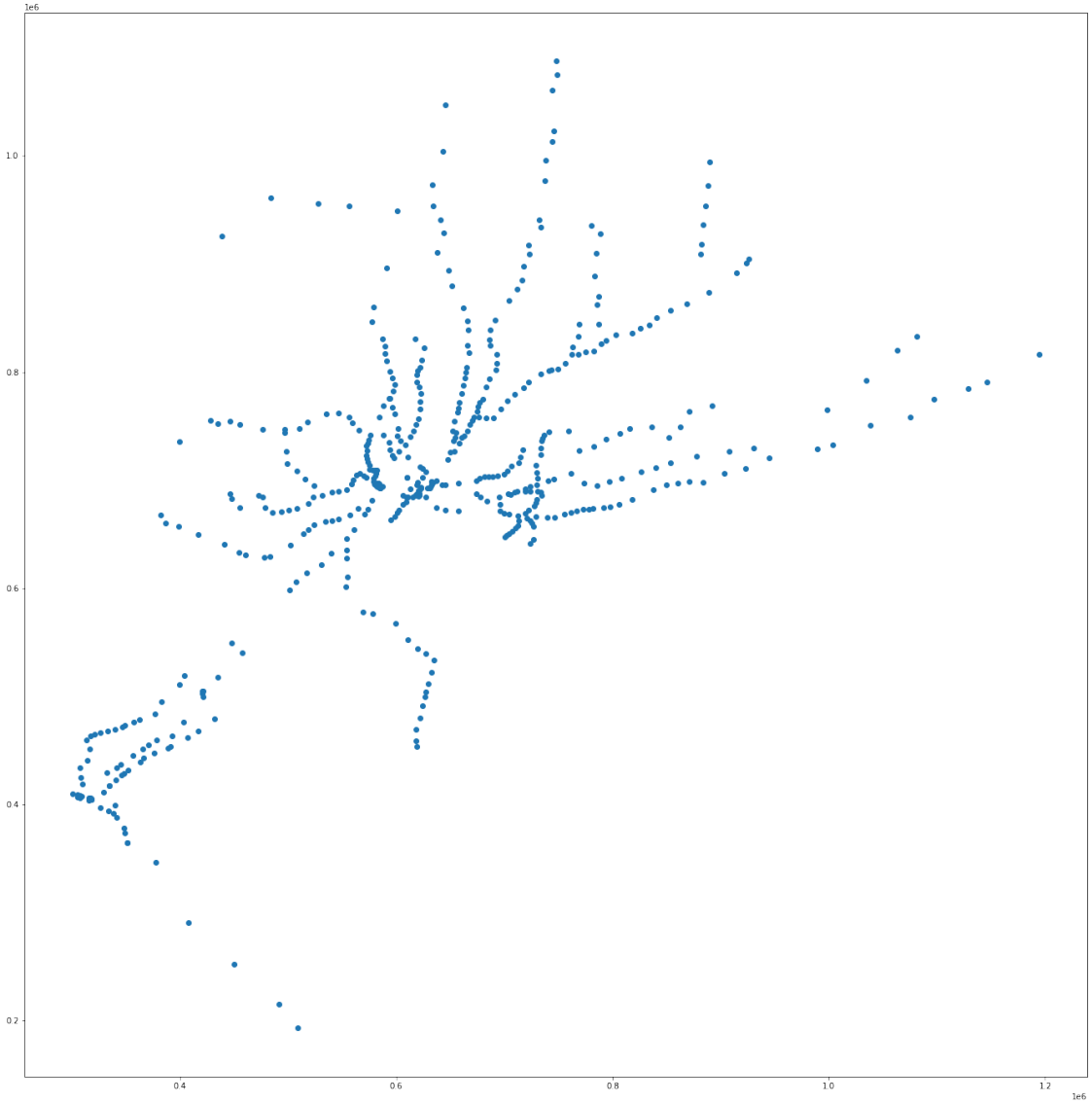
[65]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f22c5568910>
```



Let's make it look better:

[66]:
```
nymastation.plot(
            figsize=(40,24))
```

[66]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f22c6551e20>
```



6 Data analysis

Now I have the two new dataframes with combines lines and stations, I want to plot them onto the county boundary map.

[44]:
```
#import county boundary shapefile
cb=gpd.read_file('NYMRcb')
```

[45]:
```
#quick look at the dataframe--I'm looking at geometry column especially to see␣
 ↪if there is a need to convert the coordination system
cb.head()
```

[45]:
```
   cartodb_id statefp countyfp  geoid                          name  \
0           1      09      001  09001   Fairfield County, Connecticut
1          10      34      025  34025     Monmouth County, New Jersey
2          25      36      081  36081         Queens County, New York
3           2      09      005  09005  Litchfield County, Connecticut
4          19      36      027  36027       Dutchess County, New York

  subregid     atotal      aland  pop_10e  pop_10m  …  cr_oth_e  \
0       CT  836.91795  624.96958   916829        0  …       344
1      ONJ  665.31546  468.40775   630380        0  …         0
2      NYC  178.03032  108.76805  2230722        0  …      9887
3       CT  944.55528  920.56844   189927        0  …         0
4      MHV  825.34308  795.63519   297488        0  …        77

      cr_oth_m    cr_oth_c  cr_hom_e     cr_hom_m  cr_hom_c  iscommap  \
0   363.225722   64.187765         0     0.000000  0.000000         0
1     0.000000    0.000000         0     0.000000  0.000000         0
2  1864.166774   11.461840     35072  3689.568791  6.395127         0
3     0.000000    0.000000         0     0.000000  0.000000         0
4   132.008047  104.218251         0     0.000000  0.000000         0

   iscomnycre  iscomnycwo                                       geometry
0           1           1  MULTIPOLYGON (((-73.60428 41.01486, -73.60471 …
1           1           1  MULTIPOLYGON (((-73.99367 40.23651, -73.99377 …
2           1           1  MULTIPOLYGON (((-73.83039 40.60801, -73.83033 …
3           1           1  POLYGON ((-72.98325 41.63960, -73.00315 41.629…
4           1           1  POLYGON ((-73.48731 42.04964, -73.48731 42.049…

[5 rows x 222 columns]
```

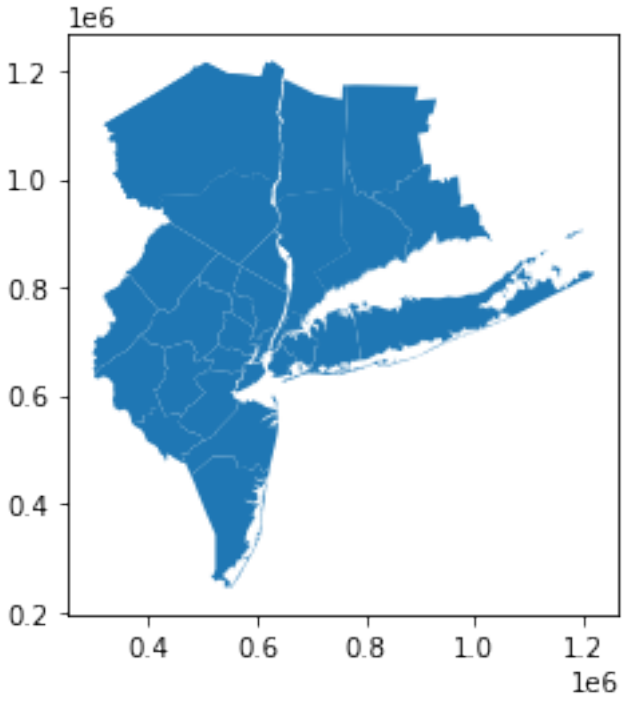
[46]:
```
#convert the coordination system to match with the line and station dataframes
cb=cb.to_crs('epsg:3424')
cb.head()
```

[46]:
```
   cartodb_id statefp countyfp  geoid                          name  \
0           1      09      001  09001   Fairfield County, Connecticut
1          10      34      025  34025     Monmouth County, New Jersey
2          25      36      081  36081         Queens County, New York
3           2      09      005  09005  Litchfield County, Connecticut
4          19      36      027  36027       Dutchess County, New York

  subregid     atotal      aland  pop_10e  pop_10m  …  cr_oth_e  \
0       CT  836.91795  624.96958   916829        0  …       344
1      ONJ  665.31546  468.40775   630380        0  …         0
2      NYC  178.03032  108.76805  2230722        0  …      9887
3       CT  944.55528  920.56844   189927        0  …         0
4      MHV  825.34308  795.63519   297488        0  …        77
```

```
      cr_oth_m    cr_oth_c  cr_hom_e     cr_hom_m  cr_hom_c  iscommap  \
0   363.225722   64.187765         0     0.000000  0.000000         0
1     0.000000    0.000000         0     0.000000  0.000000         0
2  1864.166774   11.461840     35072  3689.568791  6.395127         0
3     0.000000    0.000000         0     0.000000  0.000000         0
4   132.008047  104.218251         0     0.000000  0.000000         0

   iscomnycre  iscomnycwo                                           geometry
0           1           1  MULTIPOLYGON (((739294.387 795879.033, 739178…
1           1           1  MULTIPOLYGON (((633476.713 511467.499, 633447…
2           1           1  MULTIPOLYGON (((678032.841 647101.049, 678050…
3           1           1  POLYGON ((906689.771 1025869.682, 901318.076 1…
4           1           1  POLYGON ((767152.805 1173256.139, 767152.776 1…

[5 rows x 222 columns]
```

[47]:
```
cb.plot()
```

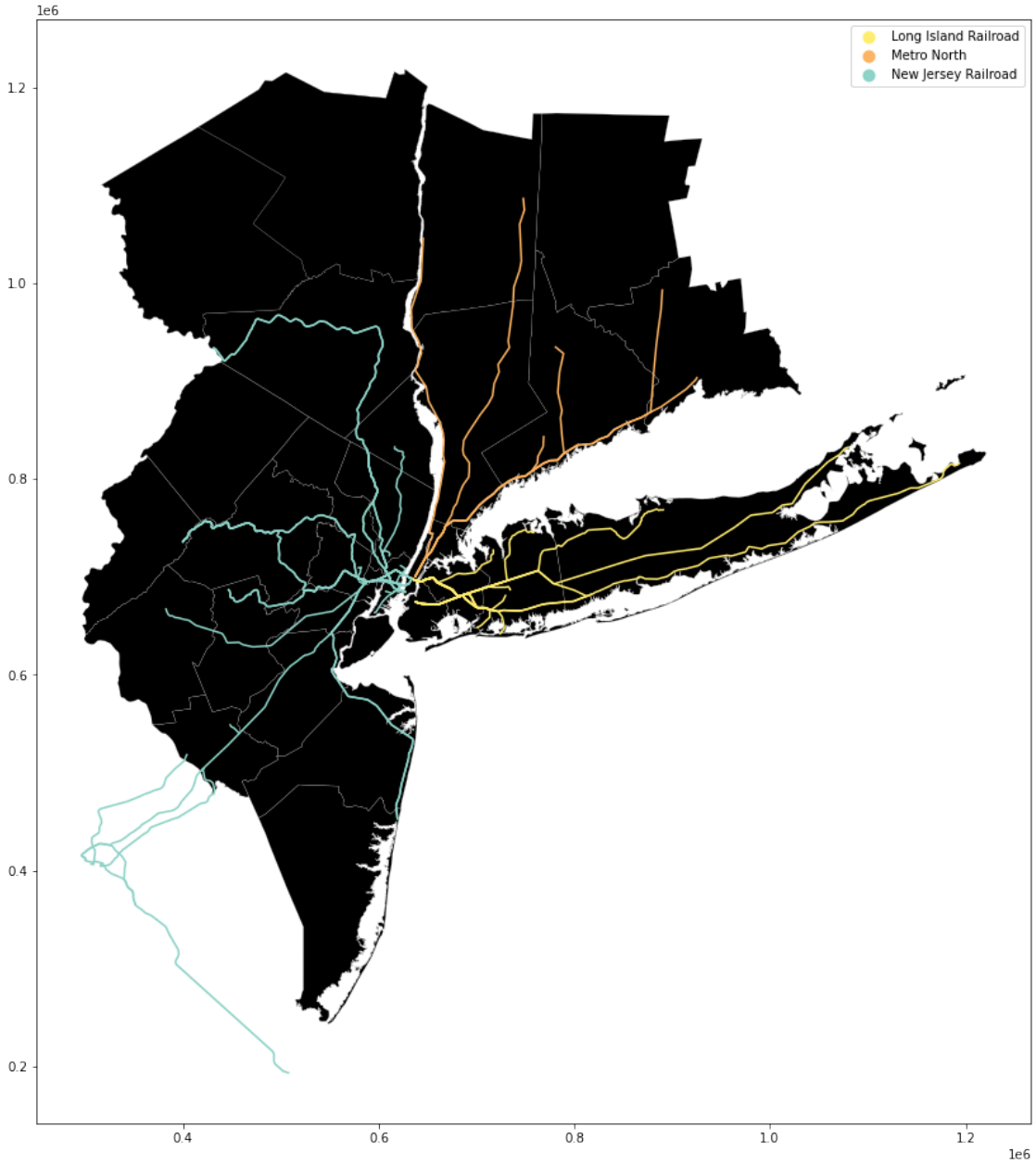
[47]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff1acda6d60>
```



Let's make it look better and put the line dataframe onto the county border map

[51]:
```
fig, ax = plt.subplots(figsize = (20,16))
nymarail.plot(column = 'Operating',cmap = 'Set3_r', legend=True, ax=ax)
cb.geometry.plot(color='black',edgecolor='gainsboro',linewidth = 0.2,ax=ax)
```

[51]: <matplotlib.axes._subplots.AxesSubplot at 0x7ff1aef36a30>



[52]:
```
#Let's add the stations on to the county boundary map
stationincounty = gpd.sjoin(nymastation, cb, op='within')
```

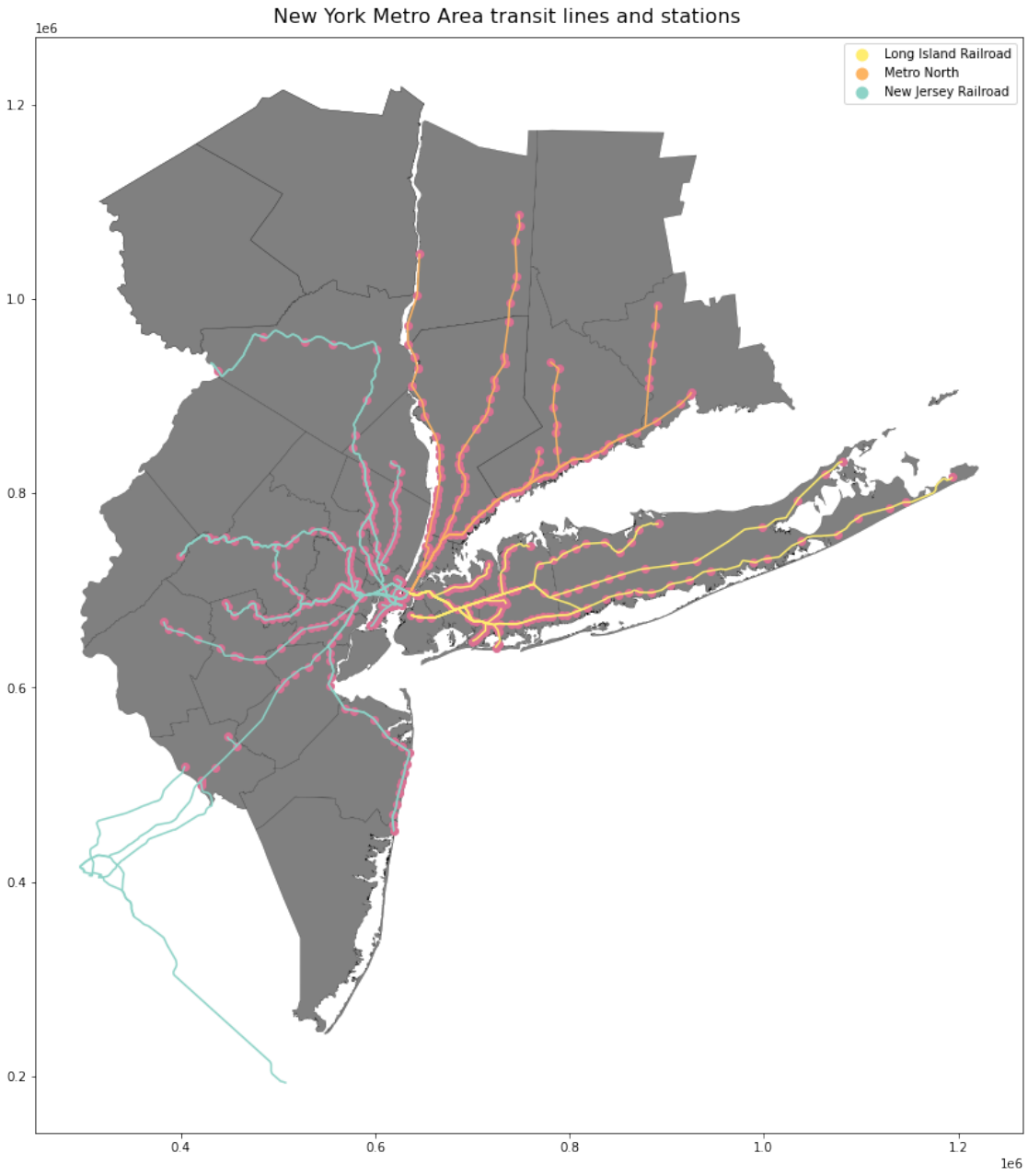
[53]:
```
stationincounty.head()
```

[53]:
```
            stationname       lat       lon                       geometry  \
0     Long Island City  40.74128 -73.95639  POINT (642750.072 695409.903)
1  Hunterspoint Avenue  40.74238 -73.94679  POINT (645407.555 695827.249)
3             Woodside  40.74584 -73.90297  POINT (657540.623 697167.271)
4         Forest Hills  40.71957 -73.84481  POINT (673726.190 687712.061)
5          Kew Gardens  40.70964 -73.83089  POINT (677612.026 684123.665)

               Operating  index_right  cartodb_id statefp countyfp  geoid  …  \
0  Long Island Railroad            2          25      36      081  36081  …
1  Long Island Railroad            2          25      36      081  36081  …
3  Long Island Railroad            2          25      36      081  36081  …
4  Long Island Railroad            2          25      36      081  36081  …
5  Long Island Railroad            2          25      36      081  36081  …

    cr_bw_c cr_oth_e     cr_oth_m  cr_oth_c  cr_hom_e     cr_hom_m  cr_hom_c  \
0  6.017308     9887  1864.166774  11.46184     35072  3689.568791  6.395127
1  6.017308     9887  1864.166774  11.46184     35072  3689.568791  6.395127
3  6.017308     9887  1864.166774  11.46184     35072  3689.568791  6.395127
4  6.017308     9887  1864.166774  11.46184     35072  3689.568791  6.395127
5  6.017308     9887  1864.166774  11.46184     35072  3689.568791  6.395127

   iscommap  iscomnycre  iscomnycwo
0         0           1           1
1         0           1           1
3         0           1           1
4         0           1           1
5         0           1           1

[5 rows x 227 columns]
```

[64]:
```
fig, ax = plt.subplots(figsize = (20,16))

nymarail.plot(column = 'Operating',cmap = 'Set3_r', legend=True, ax=ax)
cb.geometry.plot(color='Grey', edgecolor='black',linewidth = 0.2,ax=ax)
stationincounty.plot(column = 'name',color='palevioletred', legend=True, ax=ax)
fig.suptitle('New York Metro Area transit lines and stations', fontsize=16,x=0.
 ↪5,y=0.9)
```

```
/opt/conda/lib/python3.8/site-packages/geopandas/plotting.py:572: UserWarning:
Only specify one of 'column' or 'color'. Using 'color'.
  warnings.warn(
```

[64]:
```
Text(0.5, 0.9, 'New York Metro Area transit lines and stations')
```



6.1 Put stations on the map with Plotly.Express

[68]:
```
nymastation= px.scatter_mapbox(nymastation,
                        lat='lat',
                        lon='lon',
                        color='Operating',
                        hover_name="stationname",
                        mapbox_style="stamen-toner")
```

```
nymastation.show()
```

7 Conlusion

In this notebook, I combined three transit lines files and three transit stations files into two dataframs, and explore some mapping options for future analysis on transit system and migration, housing value and economic factors.