Introduction

As the third largest city in the country, Chicago, IL is often seen as a hub for urban design implementation. With the third largest population and the third largest public transportation system, Chicago faces unique challenges in how it houses and transports its residents each day. This paper aims to employ various spatial analysis techniques to investigate the accessibility of Chicago's affordable housing stock.

The Affordable Requirements Ordinance (ARO) is set by the Chicago Housing Authority and defines "affordable" as housing that costs no more than 30% of an individual's income. Additionally, units designated as affordable must be reserved for residents that make 60% or less of the Area Median Income (AMI). These units are dispersed throughout the city in a variety of developments. While affordable housing options are located throughout the city, not all units are created equal. Some neighborhoods of the city are more accessible than others, specifically in terms of proximity to public transportation. Without easy access to transportation, residents must spend more income on travel expenses, which can defeat the purpose of affordable housing. In addition to proximity to transit, some units are located in areas of the city with restrictive residential zoning codes. These codes have the potential to limit the type of buildings and services located in a neighborhood. Without walkable access to grocery stores, schools, doctor's offices, and other enterprises, an affordable unit is not nearly as effective of a tool as it can be.

In order to investigate the accessibility of affordable housing in Chicago, I use a variety of spatial analysis techniques to better understand the physical layout of Chicago's housing, and make recommendations for future development. By creating a dashboard, we can easily see the visual layout of Chicago's affordable housing units as

well as their proximity to "The L", or Chicago's public transportation system run by the Chicago Transit Authority (CTA). In addition to affordable units and public transit lines, the dashboard overlays zoning districts so we can better understand the types of neighborhoods affordable units are located in. Lastly, I employ various Python packages to analyze the makeup of each area of the city.

Data Sources

All data for this dashboard comes from open source platforms, mainly those maintained by the City of Chicago. Below are the links to each dataset, as well as a brief description of its contents and use within the dashboard.

- Affordable Rental Housing Developments
  - https://data.cityofchicago.org/Community-Economic-Development/Affordable-Rental-Housing-Developments-Map/k3g7-7kgc
  - Property Name, Property Address, # of Units, Latitude & Longitude
  - Each property is displayed on the map with a tooltip that provides the property name and number of affordable units within the building
- American Community Survey (ACS) 5 Year Data by Community Area
  - https://data.cityofchicago.org/Community-Economic-Development/ACS-5-Year-Data-by-Community-Area/t68z-cikk/about_data
  - Community Area Name & ACS Survey Data
  - This dataset contains 5-year survey responses from the ACS. Community Area boundaries were used to group affordable housing properties on the map.
- Boundaries - Zoning Districts (Current)
  - https://data.cityofchicago.org/Community-Economic-Development/Boundaries-Zoning-Districts-current-Map/7cve-jgbp
  - Shapefile containing Zoning Code and polygon data
  - Zoning districts are overlaid on map and color coded based on zoning category. Boundaries are also used for spatial analysis regarding the number of affordable units located within each one.
- Chicago Transit Authority (CTA) Data
  - "L" Lines

        - https://data.cityofchicago.org/Transportation/CTA-L-Rail-Lines-Shapefile/53r7-y88m/about_data
        - Shapefile containing CTA subway lines.
        - Rail lines are overlaid on map to show location and proximity to affordable housing units.
    - "L" Stations
        - https://data.cityofchicago.org/dataset/CTA-L-Rail-Stations-Shapefile/vmyy-m9qj/about_data
        - Shapefile containing CTA subway stations
        - Rail stations are overlaid on map to show location and proximity to affordable housing units. Location data was then used to calculate housing accessibility based on a 400m radius.

The Chicago Zoning Ordinance (Title 17, 2025) was utilized to inform the data cleaning process and zoning category formation.

Spatial Analysis Techniques

Map Construction

In order to construct the dashboard, data was first downloaded from its respective portal at data.cityofchicago.org. Affordable housing data was joined with ACS data and grouped by Community Area. Because affordable unit accessibility is the main focus of this analysis, this data layer was the first one added to the map. Properties are marked by a white square denoting the number of affordable units within that building.

Once affordable units were displayed, zoning data was cleaned and grouped based on category. The Chicago Zoning Ordinance provides detailed titles and descriptions for each zoning classification. For the sake of this map, codes were categorized under general groups such as Residential, Neighborhood, Transportation, Industrial, Downtown, and Planned Development. Categories followed a color scheme with each code having a distinct color. Please see the appendix for more details. Each

zoning code group was added as a separate layer and then added to the map. Each layer is toggleable for easier visualization, as well as a hoverable tooltip that provides further information on what each zoning classification is.

Lastly, public transit rail lines and stations were added to the map as a toggleable layer. In order to reduce visual and statistical noise, only rail lines were included rather than bus lines. Each line is colored based on its name and has a hoverable tooltip to display its name. Stations are marked by individual dots and have a hoverable tooltip to display its name as well.

Map construction was done using the Python packages Folium and Geopandas. Geopandas allows for efficient cleaning of data that would otherwise be cumbersome when done directly in arcGIS. Geopandas creates smaller geodataframes that can then be added as individual layers to a map via Folium. I prefer this method over arcpy as it incorporates both analytical and visual functionalities in one step. Folium also allows for more control over display design than other packages.

Spatial Analysis

After cleaning and combining the data, it was displayed simultaneously on the map. By using Folium, layers are easily added or subtracted from the map making visualization much easier. Tooltips allow for the user to investigate on their own what each layer is, and how they are related to each other.

The Python packages Pandas and Geopandas were then used to conduct spatial analysis. I created a buffer zone of 400m around each CTA rail station and then calculated the number of affordable units within that radius. Geopandas was also used to calculate the number of affordable units within each zoning category and construct a dataframe of this information.

Results

Visually speaking, the map appears to be very comprehensive and displays a large amount of information when all layers are selected. By selecting various layers, the user can decide which zoning category they would like to investigate further and focus on its information and physical distribution. Not only is the map a tool for housing analysis, but it provides a key visualization of zoning distribution in the city using a lens that is not often utilized by city-run maps. Figure 1 displays the entire map and Figure 2 displays a closer view of a portion of the city. As you can see, the zoning restrictions are incredibly specific, and are often broken down at the plot-level.

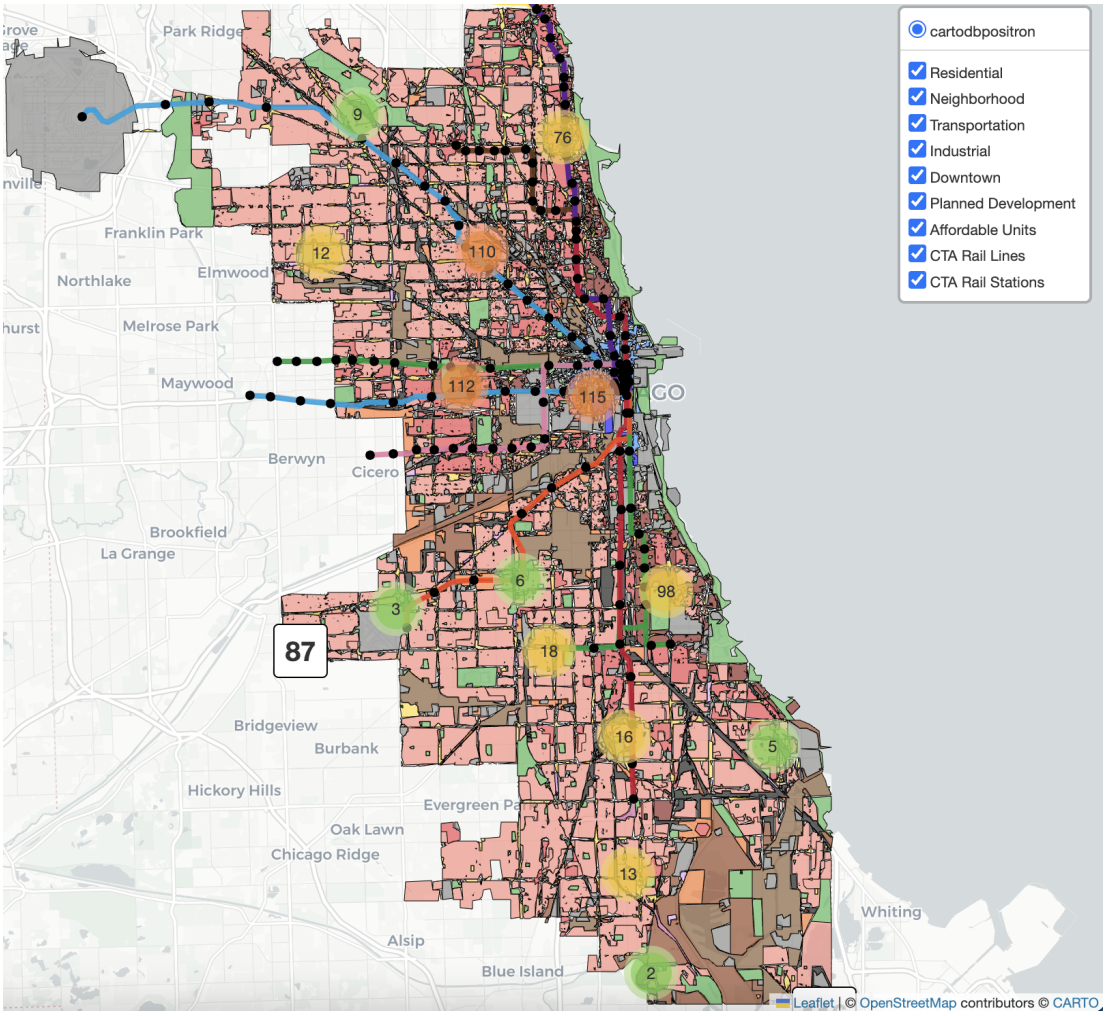

Figure 1: Map view with all layers selected

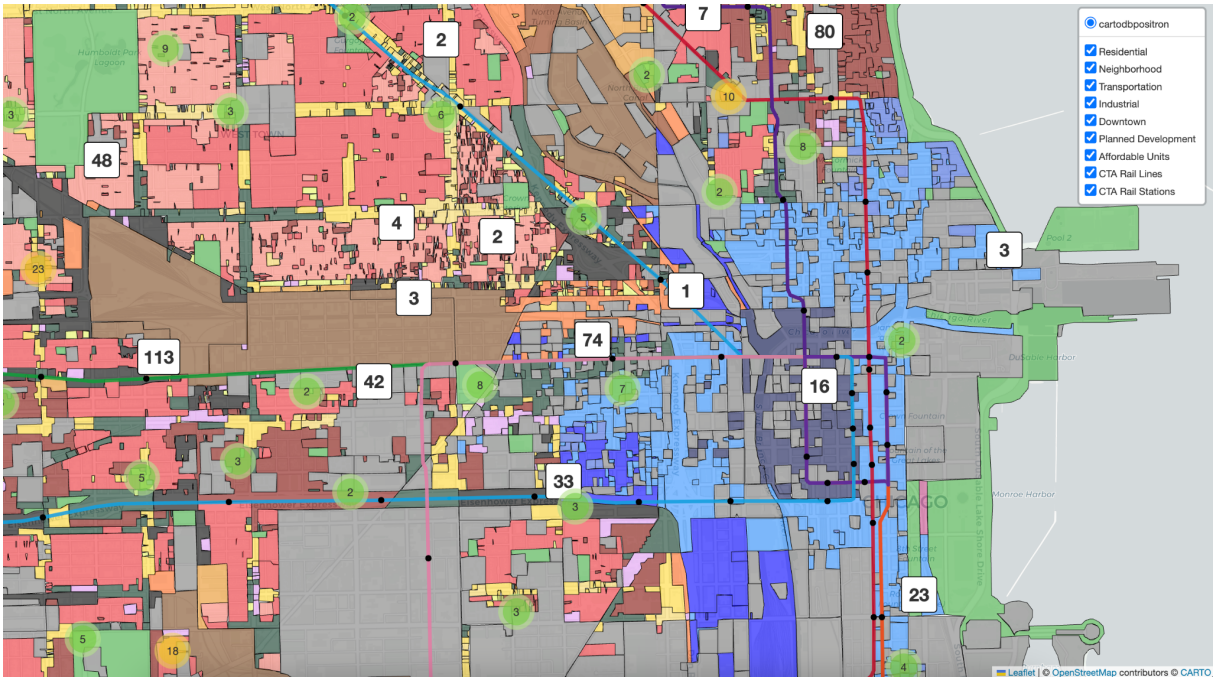

Figure 2: Closer view of map with all layers selected

In order to more easily visualize the distribution of zoning districts, the categories are able to be individually toggled on or off. In doing so, users can better see which districts tend to have more affordable housing. Additionally, users can understand how zoning impacts the overall construction of the city. As seen in Figures 3 - 5, the vast majority of Chicago is zoned for residential use, followed by neighborhood, and industrial zones.

Rather than only separating zones by single-family or multi-family units, Chicago's Zoning Ordinance also creates a "two-unit" code in between the two. These zones are strictly for duplex-style buildings and intentionally separates them from apartment buildings. In terms of coloring on the map, the more darker the shade of red, the more dense a residential structure is. Neighborhood districts also allow for residential units and are more similar to "multi-use" zoning codes typically seen in other cities across the country. Due to the less restrictive use of space, units in "neighborhood"

zones are generally more accessible and located within walking distance of businesses, services, and the like. Neighborhood zones also include parks and other public green spaces that residential zones do not allow for.

Figure 3: Residential Zones in Chicago

Figure 4: Neighborhood Zones in Chicago

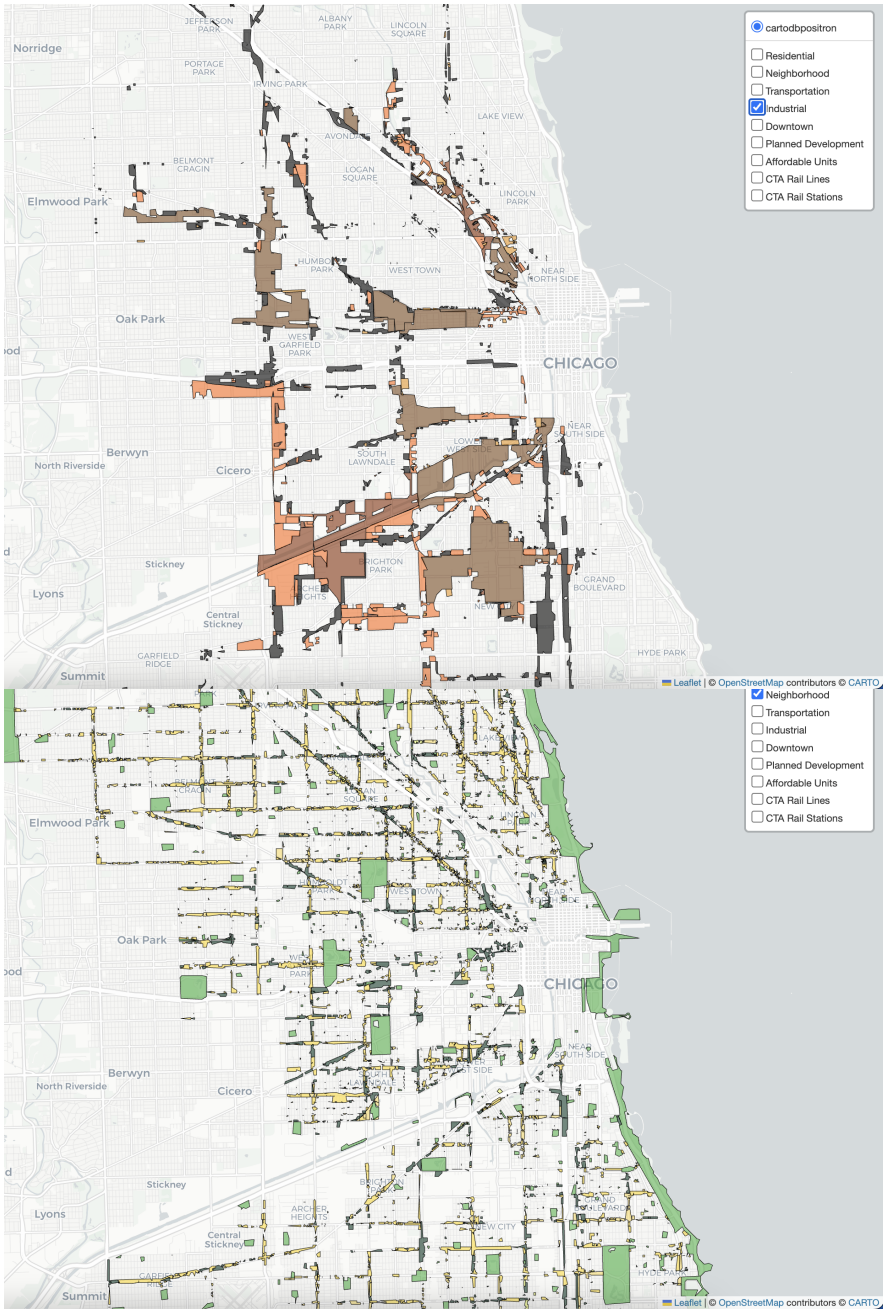

Figure 5: Industrial Zones in Chicago

The industrial zones do not take up as much space as other categories, but it is still important to note where these zones are located. A large portion of Chicago's workforce is employed by businesses and industries located in these zones. Their proximity to not only public transit but other residential zones is crucial in the assessment of housing accessibility. Because these zones are intertwined with other classifications, the city's land is used more efficiently and is made more accessible to the workers that are employed there each day.

After building the map, I utilized the Pandas and Geopandas Python packages to conduct further spatial analysis. In order to calculate the number of units in "walkable" areas, I created 400m buffer zones around each CTA station, as mentioned previously. The program then counted the number of affordable units within that buffer zone and provided the total number of affordable units surrounding each station. The first table outlines the top five stations with the highest number of affordable units nearby.

Table 1: Transit Stations and Access to Public Transit

CTA Station	# of Affordable Units within 400m
Cermak-Chinatown	795
Cermack-McCormick Place	668
Loyola	496
43rd Street	472
Morse	460

Please see appendix for entire results table

Of the top five stations, Cermak-Chinatown, Cermack-McCormick Place, and 43rd Street are located within a heavily residential zone on the southern side of the city. Loyola and More are located on the northern side of the city, closer to Evanston, but also

in residential zones. Additionally, all stations except for Cermack-McCormick Place were located on the Red Line.

Analysis was also conducted on the type of zoning district affordable housing units are most often located within. Please see the table below for an overview of these findings.

Table 2: Affordable Units per Zoning District

Zoning Classification	# of Affordable Units
Multi-Unit Residential	6,096
Neighborhood (Shopping)	3,087
Two-Flat Residential	2,814
Neighborhood (Mixed-Use)	1,096
Neighborhood (Commercial)	622
Single-Unit Residential	592
Other	938
Planned Developments	*14,389*

Results from this analysis indicated that Multi-Unit Residential zones had almost twice as many affordable units as the next closest zone with slightly over 6,000 units. Slightly over 4,500 units were located in "neighborhood" zones, meaning they occupy buildings with multiple uses within the same structure. This bodes well for our accessibility analysis as it indicates a large amount of housing within the city is located in areas that are more walkable. These findings also show that the more dense a zone is, the more likely it is to have a higher number of affordable units. One thing of note, Chicago delineates plots or zones currently under construction as "planned developments." These zones are categorized separately on the map, even though they will eventually become a different category. While we can't be sure of the type of zones

these units will be located in once complete, it is reassuring to see that the city has more than 14,000 affordable units under construction or development.

Discussion

Overall, Chicago's affordable housing stock appears to be relatively accessible. Results indicated that a large portion of units were located within walking distance of public transit, one of the main contributors to accessibility. Analysis also supports that more-dense residential zones allow for a higher number of affordable units to be placed on a smaller amount of land. Additionally, the fact that many units are located in "neighborhood" zones further supports that Chicago has accessible housing. While not perfect, Chicago is performing at a much better level than a number of other equally-sized cities. To answer the initial research question, Chicago's affordable housing is indeed accessible, and is continuing to grow as the city grows.

In terms of coding structure, I am of the opinion that the script is as efficient as possible, given constraints of this project. From top to bottom, the script runs in less than one minute and is able to produce the interactive map, as well as two different tables of analytical data. The map itself is a little noisy when all layers are displayed, but is useful when the toggling feature is employed. As mentioned before, I chose to use Folium, Geopandas, and Pandas over arcpy due to their efficiency. Running scripts in ArcGIS's online notebook can be slow at times, and requires the user to upload data in different formats in order to use them. These packages allow the analyst to directly download data from its source and immediately begin cleaning and analyzing it. While Folium requires a higher programming knowledge, it allows for more control over the aesthetics and functionality of the map itself.

While the current map is effective in its visualization and analysis of Chicago's affordable housing, future research could improve it further. Given the time constraints of an academic semester and the availability of public data, the map is limited in terms of its currentness. If provided access to real-time data, the map could update based on the vacancy rate of units, not just their location. By doing this, an interactive dashboard would be able to display the distribution of units, as well as which ones are unoccupied at the given moment. This tool would be incredibly beneficial for Chicago residents in search of affordable housing.

Additional research could also further combine analysis to better understand true cause-and-effect relationships. By investigating additional variables such as income, family size, or building age, the map would have a more in-depth analysis of Chicago's housing, not just the static variables currently at hand. Either way, urban centers across the globe are facing an affordability crisis, and tools such as these will be beneficial in developing cities in a more equitable way.

Appendix

Coding Script:

```
import pandas as pd
import geopandas as gpd
import folium
from folium.plugins import MarkerCluster
import warnings; warnings.filterwarnings( action: 'ignore',  message: 'GeoSeries.notna', UserWarning)

###Load data
zoning_data = "chicago_zoning.geojson"
acs_data = "chicago_acs_community_area.csv"
affordable_data = "chicago_affordable.csv"
zoning = gpd.read_file(zoning_data)
acs = pd.read_csv(acs_data)
afford = pd.read_csv(affordable_data)
cta_lines = gpd.read_file("CTA_RailLines.shp")
cta_stations = gpd.read_file("CTA_RailStations.shp")
print("Data read in")

###Clean housing data
acs['Community Area'] = acs['Community Area'].str.strip().str.upper()
afford['Community Area'] = afford['Community Area Name'].str.strip().str.upper()
afford_merged = afford.merge(
    acs,
    how='left',
    on='Community Area',)
afford_gdf = gpd.GeoDataFrame(
    afford_merged,
    geometry=gpd.points_from_xy(afford_merged['Longitude'], afford_merged['Latitude']),
    crs=4326)
```

```
zoning_cats = {
    "RS": "single_unit_residential",
    "RT": "two_flat_residential",
    "RM": "multi_unit_residential",
    "B1": "neighborhood_shopping",
    "B2": "neighborhood_mixed",
    "B3": "community_shopping",
    "C1": "neighborhood_commercial",
    "C2": "motor_vehicle_commercial",
    "C3": "commercial_manufacturing",
    "DC": "downtown_core",
    "DX": "downtown_mixed_use",
    "DR": "downtown_residential",
    "DS": "downtown_service",
    "M1": "limited_manufacturing",
    "M2": "light_industry",
    "M3": "heavy_industry",
    "T":  "transportation",
    "PO": "parks",
    "PM": "planned_manufacturing_district",
    "PD": "planned_development"}
```