The Density Paradox

Is density really cities’ biggest enemy in fighting COVID-19?

INF 2400 Team Assignment

Chu Li 1003026236

Jing Xie 1006567467

Harold Chiu 999066692

I. Data Story

For the data story, we created a video as below:

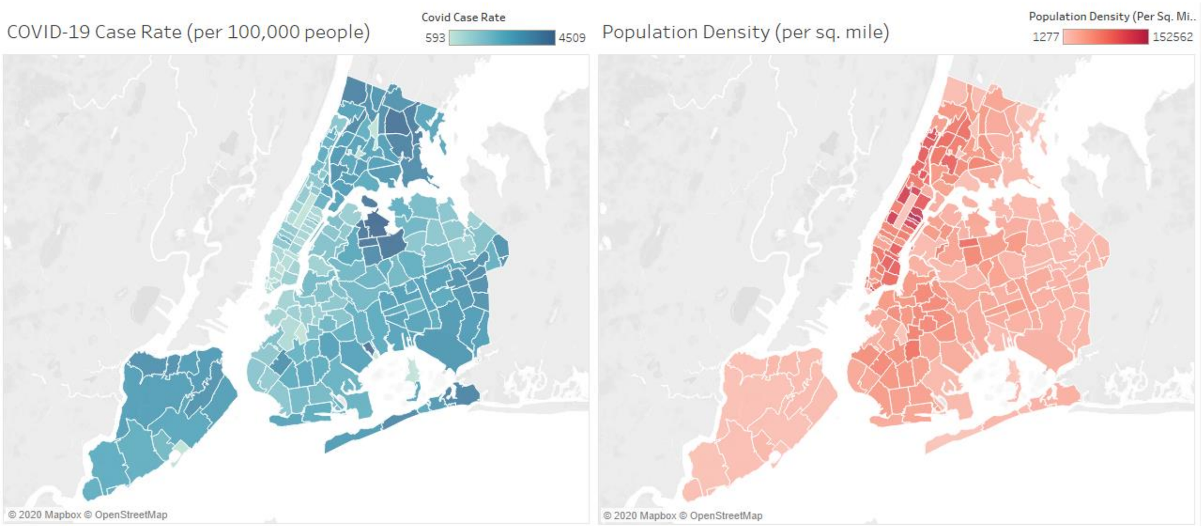
https://youtu.be/jYGMAKOsof8

II. Data Analysis

a. Early explorations

The first exploration was determining the correlation between population density of each neighbourhood in New York City and number of COVID-19 cases. This was mapped in Tableau with the use of shapefiles containing the boundaries for each neighbourhood. A map of COVID-19 cases was shown beside that of population density as seen in **Figure 1** below.

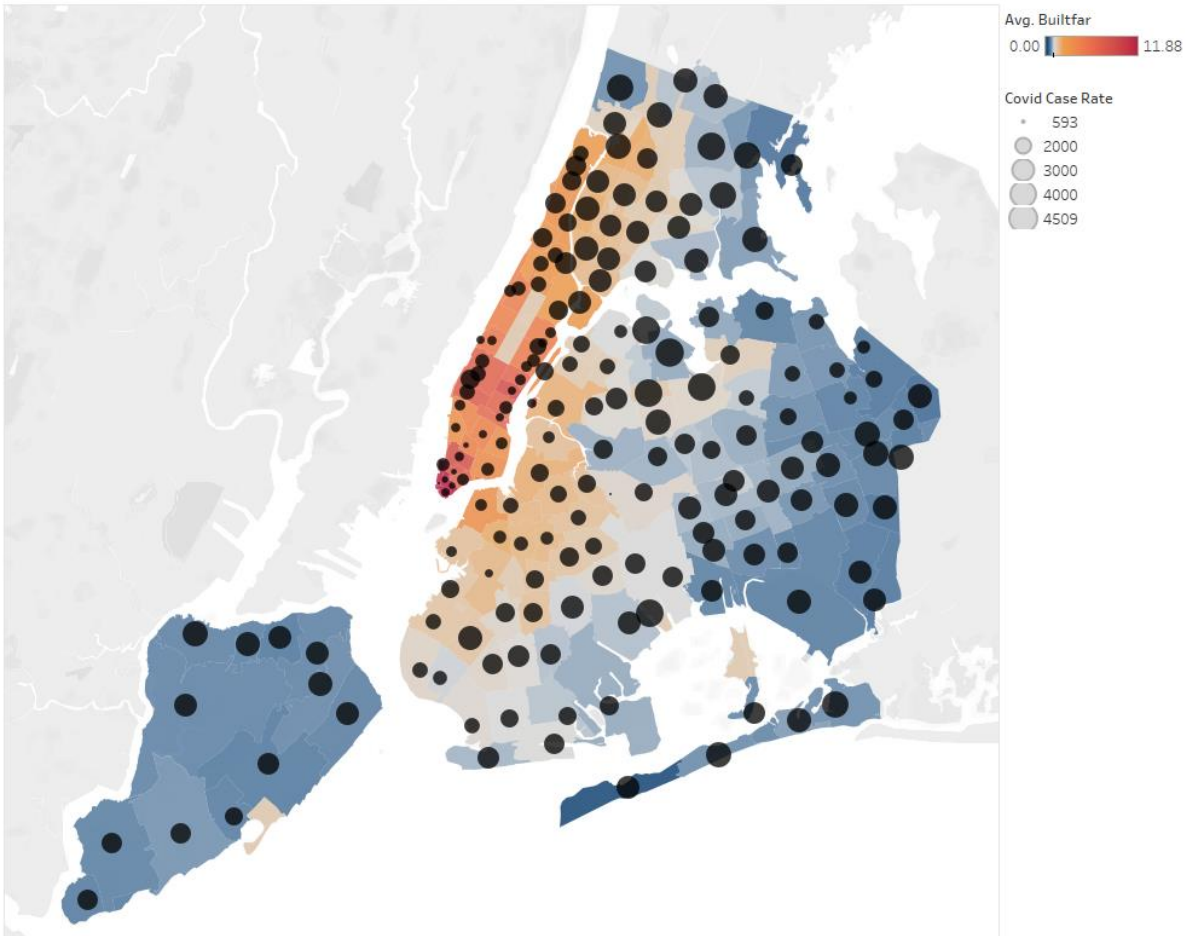
Figure 1: Initial Exploration (Density vs. COVID-19 case rate)



From observation alone, it is evident that no correlation exists between the two attributes. However, since population density fluctuates throughout the day as people travel between areas, it cannot be measured reliably, and any population figures obtained are not current. As such, we sought to find a more representative measure to replace population density. We looked at zoning maps from NYC Open Data, which differentiate between low, medium, and high density of different land use types. However, the sheer size and complexity of the dataset made it infeasible to work on. Eventually, we found that the Built **Floor Area Ratio** [**BuiltFAR**] to be a better measure for density since it reflects the relationship between the amount of usable floor area in a building to the total area of the lot (Hargrave, 2019). As a continuous numeric variable, it is straightforward to manipulate and visualize while containing sufficient information about density. We also determined **COVID-19 case rate** to be a more representative measure of the impact of the virus on the population than death count since the population of each of the neighbourhoods are not identical.

Rather than using two filled maps side-by-side, a symbol map was overlaid on top of a filled map, where dot size shows the COVID-19 case rate, and fill darkness represents the density of each neighbourhood. The revised visualization shown in **Figure 2** below is more comprehensible and concise.

Figure 2: Revised Exploration (Density vs. COVID-19 case rate)



In addition, linear regression was conducted to determine whether a correlation exists. Using the same technique, we decided not to limit the scope to density alone, but expand the analysis to encompass various economic, demographic, and social elements including income, unemployment, poverty rate, racial composition, education, healthcare availability, and insurance coverage to name a few. **Figure 3** below lists relevant features used in the analysis.

Figure 3: Features Used in Analysis		
Coefficient	**Name of Feature**	**Detailed Description**
β_1	Built Floor Area Ratio (BuiltFAR)	Ratio of usable floor area in a building to area of lot
β_2	Building structure >50 units percentage	Percentage of buildings with 50 or more units
β_3	Building structure >1 unit percentage	Percentage of buildings with 1 or more units
β_4	Population density	Number of people per square mile
β_5	Income per capita	Average annual income earned per person
β_6	Household income	Average annual household income
β_7	Poverty rate	Percentage in population aged 18 to 64 living in poverty
β_8	African American percentage	Percentage of African American people in population
β_9	Education (Bachelor's or greater)	Percentage of people with Bachelor's degree of greater
β_{10}	Healthcare availability	Number of healthcare facilities
β_{11}	Healthcare insurance	Percentage of people without healthcare insurance

Four multilinear regression models were generated and compared in Python to determine which combination of attributes had highest explanatory power for density. The models are listed in **Figure 4** below.

Figure 4: Description of Models			
Name	**Model**	**Metrics**	**Target**
Model 1	Case Rate = $\beta_0 + \beta_1 X_{1i} + \beta_9 X_{9i} + \beta_5 X_{5i}$	BuiltFAR, Education, Income per capita	COVID-19 Case Rate
Model 2	Case Rate = $\beta_0 + \beta_4 X_{4i} + \beta_9 X_{9i} + \beta_5 X_{5i}$	Population density, Education, Income per capita	COVID-19 Case Rate
Model 3	Case Rate = $\beta_0 + \beta_9 X_{9i} + \beta_5 X_{5i}$	Education, Income per capita	COVID-19 Case Rate
Model 4	Death Rate = $\beta_0 + \beta_{11} X_{11i} + \beta_7 X_{7i} + \beta_8 X_{8i}$	Health insurance, poverty rate, and percentage of African Americans	COVID-19 Death Rate

b. Story paths

The first story we considered was to test the statement made by certain politicians that density is a driving factor for COVID-19 severity. Several news articles refer to New York Governor Andrew Cuomo's statement during a COVID-19 briefing on April 13, 2020 in Albany, New York that **"[This level of infection] is about density. It's about the number of people in a small geographic location allowing that virus to spread"** with the word "**DENSITY**" in all capital letters shown on the presentation slide. He continues to say, **"the dense environments are it's feeding grounds."** referring to the relatively high severity of COVID-19 cases in New York City at the time (Cuomo, 2020).

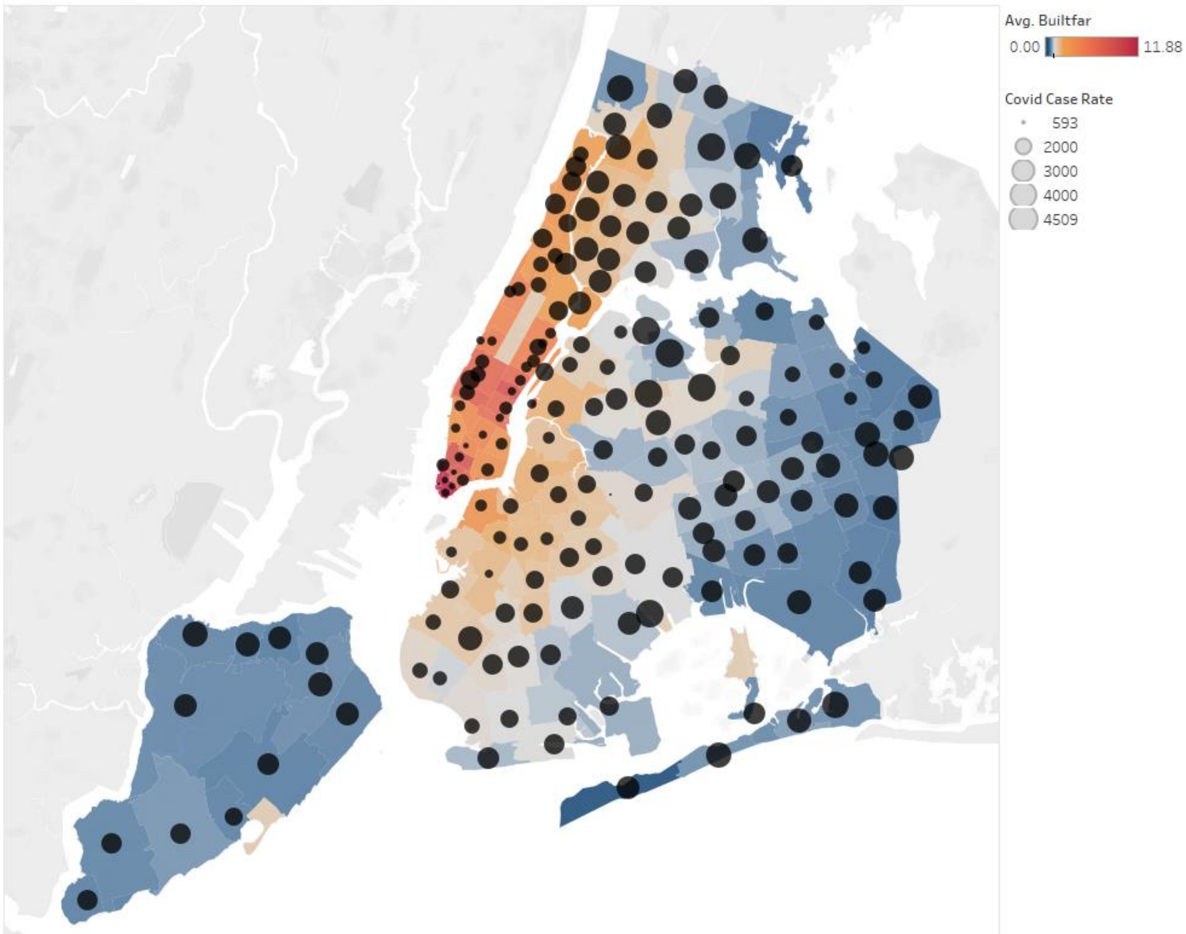
We chose to examine this because there are numerous countries around the world which do not agree with the aforementioned statement. For instance, Hong Kong, Taiwan, and South Korea all have high population densities, but relatively low COVID-19 infection rate despite being geographically closer to the presumed source of the virus (COVID-19 Stats Ph, 2020).

While we expected to find no statistically significant correlation between density and COVID-19 infection rate, we decided to take the analysis one step further to investigate economic, demographic and social elements to make the story more convincing. Thus, our story progresses to examine income, unemployment, poverty rate, racial composition, education, healthcare availability, and insurance in relation to COVID-19 infection rate.

c. Data story support

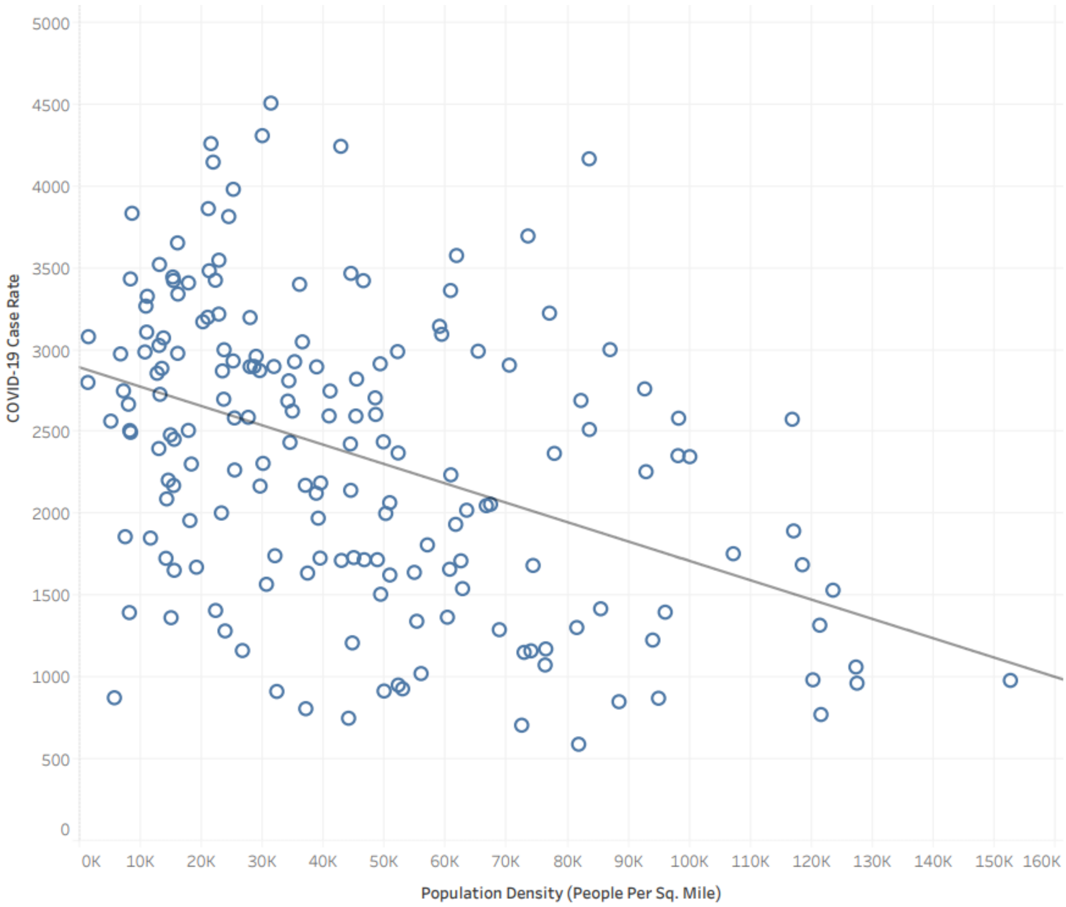
We hypothesize that density does not have a positive linear correlation with the COVID-19 infection rate. Taking Built Floor Area Ratio as a measure of density for each neighbourhood in New York City, and COVID-19 infection rate data at the neighbourhood level, the two factors were overlaid onto a map of New York City shown in **Figure 2** repeated below.

Figure 2: Revised Exploration (Density vs. COVID-19 case rate)



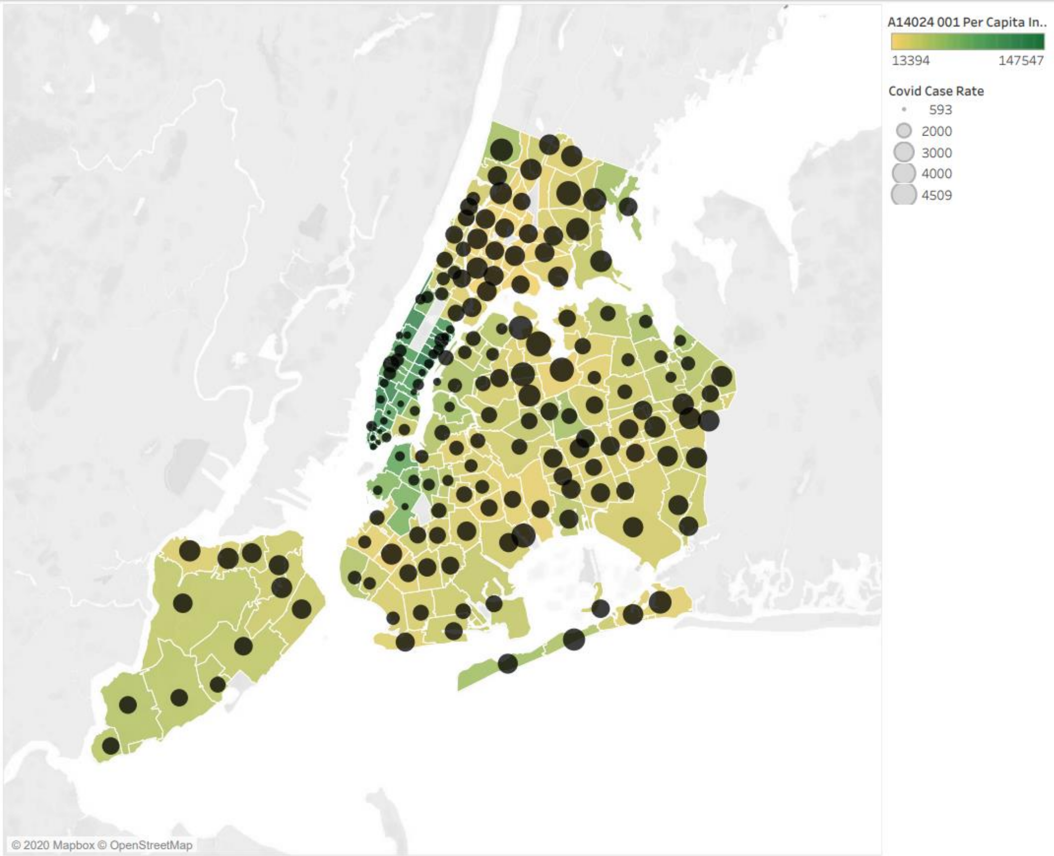
Red regions have higher density, and blue regions have lower density. For COVID-19 infection rate, the size of the dot on each neighbourhood indicates the infection rate. If density and infection rate were indeed positively correlated, we would expect to see red regions with larger dots, and blue regions with smaller dots, which is not the case in **Figure 2**. As such, it is evident that no positive linear correlation exists. A similar analysis was conducted using population density per square mile, a different measure for density, which yielded the same result. Linear regression analysis was conducted to validate these observations. Surprisingly, **Figure 3** below shows a slightly *negative* correlation between population density and infection rate. We will investigate the reasoning behind this observation further in subsequent analyses.

Figure 3: Population density vs. COVID-19 case rate



Having proven the hypothesis, the next step was to examine socioeconomic and demographic features by neighbourhood. Using similar techniques as the above, subsequent analysis revealed education and income to be the strongest correlates to infection rate. **Figure 4** below shows the map of Income per Capita vs. COVID-19 case rate, where darker green regions have higher income, and larger dots represent greater infection rate.

Figure 4: Income per Capita vs. COVID-19 case rate



Evidently, areas of higher income tend to have lower infection rate. Thus, we have sufficient evidence to disprove the claim that density and COVID-19 infection rate are positively correlated. In fact, linear regression showed the opposite to be true. We decided to expand the scope of the analysis to include looking to other predictors of COVID-19 infection rate, including income and education. In subsequent steps we used multilinear regression to model the relationships between different predictors and infection rate.

I. Storytelling Analysis

a. Audience:

1. Targeted audience

Our data story is targeted at anyone who believes that urban density is the key determinant behind a city's COVID-19 severity. We are especially focused on the group of journalists, reporters, social media influencers who hold this kind of opinion and may influence a wide range of audience by broadcasting their own opinion.

2. Reasons for choosing audience group

During a pandemic, public behaviour can be easily swayed and misguided by misinformation. It is crucial that people who have the capacity to influence the general public do not jump to conclusions. Connecting the dots between density and the viral transmission seems plausible. However, purely blaming the situation on urban density could have severe consequences. In the short term, this will diverge people's attention from other critical causes of the catastrophe, such as a flawed healthcare system and policy deficiencies. In the long term, promoting urban sprawl can lead to detrimental outcomes, such as habitat loss, biodiversity reduction, increased air pollution, obesity, hypertension and social segregation. The one-time pandemic should not erase the efforts of urbanists who strived to revert the urban development mistakes of the industrial era.

3. Expected outcomes:

- To understand the fact that density is not correlated with the infection rate of COVID 19, and that viral outbreaks have stronger correlation with social behaviours, healthcare systems and quality of governance.
- To understand that curbing the virus from escalating is achievable in densely populated cities through measures such as intensive testing, contact tracing and responsible social behaviour.
- To understand that urban sprawl's detrimental effects on climate change, habitat loss, and biodiversity reduction would eventually increase the risk of zoonotic disease outbreaks among humans.
- To understand that "high density" is different from "overcrowding" and that dense concentrations of people are necessary for a city to flourish, as they bring cities liveliness, safety and convenience.

- To understand that individual behaviours can have much larger influence during the pandemic.

b. Reasons for choosing the medium:

We choose to present our data story through a short video as it has increasingly become prevalent in both practice and academia. Scholars have defined data videos as “custom motion graphics combining both visual and auditory stimuli to promote a data story” (Amini et al., 2015). Distinguished media outlets including the New York Times and Vox have rapidly embraced this medium, releasing short videos of narrated data visualizations to the general audience.

As one of the seven genres of narrative visualization, data videos enjoy the following advantages:

- **Effectiveness**

Data videos are capable of exposing the audience to an extensive amount of information through a narrated structure within short periods of time, thus making it a highly impactful form of presentation.

- **Flexibility:**

Data videos encompass a wide spectrum of visualization techniques and storytelling structures, which offers the flexibility of customizing stories to make maximum impact.

- **Emotional engagement:**

Instead of the conventional, rigid explanation of the figures and facts, data videos are effective in bringing out the audience’s emotional responses. When human emotions are aroused, more parts of the brain are engaged in the process, making the story itself more memorable (Zak, 2013).

- **Shareability:**

Studies indicate that people share social video 1200% more than simple text and static pictures combined. In the age of widespread social media influence, it’s important to present stories in a format that can be easily shared across social platforms (“Benefits Of Motion Graphics,” 2019).

II. Next steps

1. To Maximize the strength of video storytelling

Given that it is our first time creating a data story using the video format, we have encountered various challenges. There are several directions we would like to follow in the next step to maximize the strength of video storytelling.

First of all, the current storytelling pace in the video remains slow, resulting in a total length of around seven minutes. The main reason for this is that the overall narrative is somewhat lengthy. In addition, the introduction part of the current video is verbose and lacks attractiveness, such that the overarching theme of the data was not introduced promptly.

2. To improve the persuasiveness of data

We attempt to convey in the data story that no positive linear correlation exists between COVID-19 infection rate and density. Based on the data analysis we put forth, we believe the argument is convincing. However, the observation of the effects of some other factors, such as the coverage of healthcare facilities, is insufficient for adding value to the story. Going forward, we would like to increase the depth of storytelling regarding the other factors used in the analysis to address this.

In addition, it would also be more persuasive if we could select a specific neighbourhood with representative data to provide a complete story of it, covering all the factors with a real case. Explaining the status of the density level with building layouts, listing out the healthcare facilities in the area, and using more infographics to display information would also help improve persuasiveness.

3. To introduce time series analysis

The current data story uses the NYC Health COVID-19 dataset as of June 28th, 2020. Having a larger time frame would enable us to explore the data story through time-series analysis. For example, COVID-19 severity could be analysed over time in response to changes in government policy on certain dates. Furthermore, we could explore how the infection rate in New York City responded to the government's implementation of certain policies such as travel restrictions and physical distancing guidelines.

III. Data Sources

1. **NYC Health COVID-19 dataset**

   Link: https://www1.nyc.gov/site/doh/covid/covid-19-data.page

   Key fields: **[ZipCode], [COVID_CASE_RATE]**

   Summary: The COVID-19 infection rate data are sourced from the NYC Health COVID-19 dataset, which is publicly available and updated regularly (NYC Health, 2020). The file of interest is "**data-by-modzcta.csv**" which contains data by **Zip Code [ZipCode]**, the foreign key which will help us to link datasets together. There are 10 attributes and 1,913,436 records. COVID-19 infection rate is contained in **[COVID_CASE_RATE]** which is reflected as the number of infected per 100,000.

2. **Primary Land Use Tax Lot Output (PLUTO) version 4 dataset**

   Link: https://www1.nyc.gov/site/planning/data-maps/open-data/dwn-pluto-mappluto.page

   Key fields: **[ZipCode]**, **[BuiltFAR]**

   Summary: The Primary Land Use Tax Lot Output (PLUTO) version 4 dataset is a publicly available dataset that contains extensive land use and geographic data by region in New York City (NYC Planning, 2020). There are 90 attributes and 858,986 records. The attribute we are interested in is **Built Floor Area Ratio** [**BuiltFAR**], which reflects the relationship between the amount of usable floor area in a building to the total area of the lot (Hargrave, 2019). This is our primary measure for density for the analysis. **Zip Code** [**ZipCode**] is the foreign key.

3. **American Community Survey Data dataset**

   Link: https://www.census.gov/programs-surveys/acs/data.html

   Key Fields: Zip code **[ZCTA5]**, Population Density (Per Sq. Mile) **[A00002]**, Per Capita Income **[A14024]**, Household income **[B14001]**, Educational Attainment for Population 25 Years and Over **[A12001]**, Race **[A03001],** Poverty Status in for Population Age 18 to 64 **[A13003B]**, and Health Insurance **[A20001].**

   Summary: The American Community Survey Data dataset is a publicly available dataset that contains many relevant features about the American population including population density, per capita income, household Income, education level, racial composition, poverty rate and health insurance coverage to name a few (United States Census Bureau, 2020). The foreign key is zip code **[ZCTA5]**. Population density **[A00002]** will be used as a secondary measure of density to validate results. The data is sourced from the United States

Census Bureau and is updated on an ongoing basis. Individual attributes are selected on the web portal for export. As such, the size and shape of the dataset varies.

4. **Health Facility General Information dataset**

Link: https://health.data.ny.gov/Health/Health-Facility-General-Information/vn5v-hh5r

Key Fields: **[Facility Zip Code], # of Facilities per neighbourhood**

Summary: Healthcare availability was obtained from the Health Facility General Information dataset which is maintained by the New York State Department of Health (New York State,2020). There are 36 attributes and 4001 records, where each record represents one healthcare facility in New York City. While the ideal measure would be capacity and coverage by neighbourhood, such data were not readily available. Thus, we are forced to use the number of healthcare facilities in each neighbourhood. [**Facility Zip Code**] is the foreign key.

IV. Individual Contributions

Throughout the project, our team worked collaboratively together to bring the project to fruition. Below is a breakdown of our individual contributions:

Harold:

- Exploring the data: collaborated on the initial data exploration.
- Data visualization: Collaborated on Tableau mapping visualizations, did the Tableau linear regression analysis, and did the Python multilinear regression models + 3D view.
- Data story: recorded audio voiceover, collaborated on the analysis, contributed to script writing.
- Report: Wrote Data Analysis and Data Sources, and proofread the report.

Chu:

- Exploring the data: collaborated on the initial data exploration.
- Data visualization: collaborated on the Tableau mapping visualizations.
- Datastory: collaborated on data analysis and the structure of the story, and contributed to the video editing and script writing.
- Report: contributed to the writing of the Storytelling Analysis and format editing.

Jing:

- Exploring the data: collaborated on the initial data exploration.
- Data visualization: collaborated on the Tableau mapping visualizations.
- Datastory: collaborated on the data analysis and the structure of the story, and contributed to the video editing and script writing.
- Report: contributed to the writing of the Next Steps and format editing.

VI. References

a. Existing Research

Densely populated cities are not necessarily more vulnerable during COVID-19.

Although journalists have written headlines claiming density as the city's "big 'enemy'" (*Density Is New York City's Big 'Enemy' in the Coronavirus Fight - The New York Times*, n.d.) during COVID-19, blaming the pandemic outbreak on urban concentration is an oversimplified approach. Scholars have repeatedly written about cities that are dense and proximate to China, like Hong Kong, Singapore, Taiwan, have managed to spare themselves from a major outbreak of COVID-19, owing to their robust healthcare systems and quick response to the pandemic. (Badger, 2020; Hendrix, 2020)

Urban density has been proven to promote healthier living environments

The 'smart growth' theory in urban planning advocates compact development around urban centers in order to avoid urban sprawl. In Jane Jacob's most influential work *"The death and life of American cities",* she contended that "dense concentrations of people are one of the necessary conditions for flourishing city diversity" as they bring cities "liveliness, safety, convenience and safety." People should never confuse "high densities with overcrowding" (Jacobs, 1961). Emily Badger, who writes about urban policies for the New York Times, elaborated on this issue. Density "makes mass transit possible", "allows for more affordable housing", creates walkable environments, enables people to "pool risks" and supports a stronger public health system (Badger, 2020). In Michael Hendrix's piece titled "Density and Disease', he looked at the issue from a healthcare perspective, arguing that dense cities are "better equipped to fight infectious disease" with "higher concentrations of hospitals, medical professionals and public-health officials" (Hendrix, 2020).

c. Datasets

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Appendix

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