Transference Vulnerability Assessment: Linking Social, Health, and Land-Use Factors With COVID-19 Infection

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) is a disease caused by a virus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). It has caused significant and multidimensional damages around the world. However, the impacts of the pandemic are rarely equal across communities. Communities have been shown to be disproportionately affected by threats from COVID-19 due to underlying factors such as income disparities, low education levels, the lack of insurance, limited transportation options, and poor baseline health conditions. Therefore, knowledge about the influence of these underlying factors on the community-level prevalence of the disease as well as their spatial patterns is critical for reducing infection and mortality rates during disease outbreaks.

Nonetheless, most, if not all, of the existing studies examining the influence of these underlying factors were far from comprehensive – they only considered a limited number of underlying factors or factors from a particular domain. This situation can weaken the validity of their conclusion regarding the relationship between their factors of interest and community-level COVID-19 infection. Furthermore, they have largely left the land-use factors unexplored. These gaps in the existing literature necessitate a comprehensive examination of the underlying factors influencing the community-level spread of COVID-19, which is the goal of our study.

RESEARCH QUESTIONS

- Where are the hotspots of COVID-19 infection in Houston at the Super Neighborhood scale (a sub-municipality unit unique in Houston)?
- What socioeconomic, health, and/or land-use factors influence the transference vulnerability – the probability of a community to transfer viruses/diseases during a global outbreak – of COVID-19 on the Super Neighborhood level?

METHODS

Case-study city: Houston, given the substantial socioeconomic, health, and land-use differences in different parts of the city.

Scale of analysis: Super Neighborhood, given that it is the unit local policies commonly refer to and that it is more fine-grained than many alternative scales.

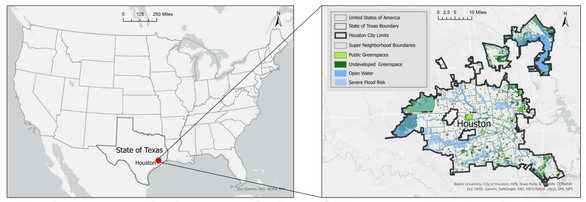

Figure 1: Location of Houston and the distribution of green spaces and flood risk within Houston

Variables: Based on the knowledge from existing literature, we included in our studies a broad range of factors (n=29) which might influence the community-level prevalence of COVID-19:

Dependent variable
- Count of active COVID-19 cases (per 10,000)

Independent variable - Health
- Persons with a disability (%)
- Adults with cancer (%)
- Adults with diabetes (%)
- Adults who experienced a stroke (%)
- Adults who experienced coronary heart disease (%)
- High blood pressure prevalence (%)
- Adults with chronic obstructive pulmonary disease (%)
- Adults with current asthma (%)
- Adults who smoke (%)
- Adults who are obese (%)

Independent variable - Land use
- Developed low intensity (%)
- Developed medium intensity (%)
- Developed high intensity (%)
- Developed open space (%)
- Undeveloped open water (%)
- Undeveloped green space (%)

Independent variable - Socioeconomic
- Average number of people per unit of land area (persons per sq mi)
- Age 65 years and over (%)
- Non-Hispanic White population (%)
- Non-Hispanic Black population (%)
- Hispanic population (%)
- Non-Hispanic Asian population (%)
- Non-Hispanic Other population (%)
- Median household income ($)
- Families living below poverty level (%)
- Educational attainment less than a high school diploma (%)
- Adults without health insurance (%)
- Households that are linguistically isolated (%)
- Households without a vehicle (%)

Data analysis: We began by performing four rounds of statistical assessments on the variables to check against potential statistical issues and filter away factors unlikely to influence COVID-19 prevalence:
- Spearman correlation coefficients and corresponding scatter plots for each of the 29 explanatory variables against the dependent variable, each fitted with a LOESS curve
- Two-sample t-test
- Multicollinearity assessment
- Bivariable linear regression analysis

24 independent variables remained after the tests. We then utilized all these variables in our multivariable linear regression analysis.

RESULTS

We judged whether the COVID-19 prevalence rate of a Super Neighborhood was high by comparing it with other Super Neighborhoods. Most of the Super Neighborhoods located northeast to the center of Houston had either the highest or the second highest quartile of infection rate. Therefore, we argue that this area was Houston's hotspot of COVID-19 infection.

Meanwhile, our multivariable linear regression model was statistically significant in predicting the active COVID-19 case counts in Houston's Super Neighborhoods ($F=15.61$, $p<0.0001$). It identified one socioeconomic factor, one health factor, and one land-use factor as the significant factors.

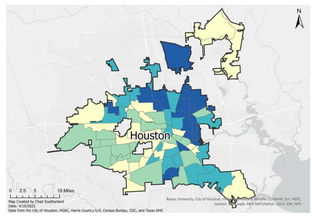

Figure 2: The distribution of COVID-19 cases per 10,000 residents

Table 1: Descriptive statistics of the dependent variable and the three significant independent variables

Factor type	Variable	Measurement	Mean	Range	Standard deviation
Dependent	Active cases	Count of active COVID-19 cases (per 10,000)	15.57	5-44	6.97
Health	Coronary heart disease (CHD) prevalence	Adults who experienced CHD (%)	6.38	2.7-12	1.92
Socioeconomic	White race/ ethnicity	Non-Hispanic White population (%)	22.98	1-77	22.52
Land use	Medium development intensity	Developed medium intensity (%)	38.47	5.22-85.44	18.60

Table 2: Results of the multivariable regression model about the statistically significant variables

Variable	Coefficient	Standard error	*t*-ratio	*p*-value
Coronary heart disease (CHD) prevalence	1.025	0.411	2.49	0.015*
White race/ethnicity	-0.090	0.036	-2.52	0.014*
Medium development intensity	-0.079	0.034	-2.36	0.021*

* $p<0.05$

Socioeconomic factor: Percentage non-Hispanic White

The institutional conditions encountered by the non-Hispanic White population are likely to explain the significance of this factor.
- Non-Hispanic White peoples are less likely to work in positions requiring frequent close-proximity person-to-person interactions, protecting them from exposure to SARS-CoV-2.
- Testing sites are commonly concentrated around neighborhoods with a higher share of non-Hispanic White families. This can offer non-Hispanic White families easier access to COVID-19 testing, allowing them to practice self-isolation earlier if tested positive.

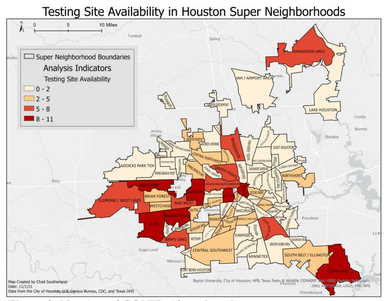

Figure 3: Number of COVID-19 testing sites

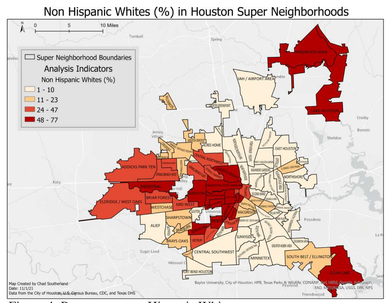

Figure 4: Percentage non-Hispanic White

Socioeconomic factor: Prevalence of coronary heart disease history

There are at least three possible explanations for this finding.
- The typical CHD medicine makes CHD patients biologically more prone to developing COVID-19.
- That an individual has a history of CHD can indicate that they can be living in an unhealthy living environment or having an unhealthy living style, which can increase their susceptibility to COVID-19.
- Individuals with a history of CHD are more likely to be symptomatic during an active COVID-19 infection. A clear presence of symptoms may encourage these individuals to seek testing, resulting in disproportionately more COVID-19 cases being reported among patients with a CHD history.

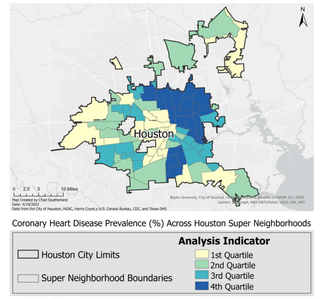

Figure 5: The prevalence of CHD history

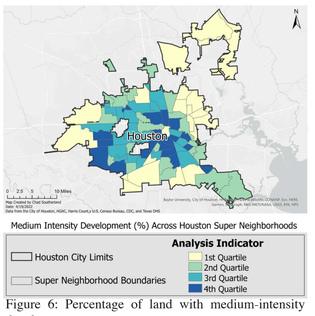

Figure 6: Percentage of land with medium-intensity development

Socioeconomic factor: Prevalence of coronary heart disease history

This finding can be the result of the fact that localities consisting primarily of land with medium- or high-intensity development tend to be more urbanized communities with stronger economies, better access to basic necessities and medical services, and more opportunities for high-tech jobs that permit remote work. The influence of this land-use factor can also arise because governments understand that a COVID-19 outbreak in more intensely developed areas can have far-reaching ramifications. This could facilitate governments to have stricter implementations of COVID-19 preventive measures there.

DISCUSSION

We compared two Super Neighborhoods in Houston – Neartown/Montrose and East Little York/ Homestead – to illustrate the broader policy issues that enabled the three significant factors to influence the active COVID-19 case count.

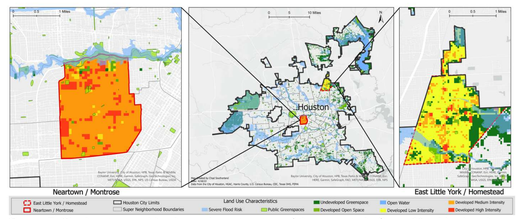

Figure 7: The location and land-use characteristics of the case-study Super Neighborhoods

Issue 1: Negligence of disparities

As demonstrated, baseline disparities can worsen the spread of COVID-19. However, Houston's planning department paid insufficient attention to these disparities. Even the single statement did not specifically aim to narrow the disparities but to "spend money wisely". It was likely that Harris County paid even less attention to these disparities. It was reflected in its complete lack of mention of disparities in *Vision for Tomorrow*.

Issue 2: Difference in collective efficacy

If a Super Neighborhood has a high degree of collective efficacy, it can work bottom-up to improve the disparities heightening its COVID-19 rate. Yet, some Super Neighborhoods lagging behind in the disparities also lack collective efficacy. The planning documents of Houston contained no mention of such a difference. This disables any policy aiming to promote collective efficacy to prioritize the lag-behind communities.

CONCLUSION

Based on the findings and discussion summarized abvoe, several policy implications can be derived from our study:
- The area to the northeast of central Houston was where policymakers should have prioritized their COVID-19 prevention/treatment resources at the time of the study.
- In the case of any future outbreak, policymakers should prioritize their resources to communities with a lower percentage non-Hispanic White, a lower proportion of its land developed with medium intensity, and a higher prevalence of coronary heart disease history.
- To more fundamentally address the high COVID-19 prevalence in some particular communities, policymakers should help communities lagging behind – in terms of occupation structure, testing-site availability, baseline CHD condition, development intensity, and collective efficacy – to catch up.