Mid-point progress report
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CPLN 680

Spatial accessibility to the COVID-19 testing sites and the driven factors behind in NYC

Introduction

With emerging new variants, the COVID-19 has been spreading among the Unites States and posing health and socioeconomic threatens. Since the outbreak of COVID-19, New York City (NYC) became the pandemic epicenter (Cordes & Castro, 2020). Fueled by the Omicron variant, a single-day peak of 50, 803 COVID-19 cases were reported in NYC on January 3rd (Kekatos, 2022). The surge of confirmed cases has exacerbated some challenges that many cities like NYC are facing with, such as the unequal distribution of medical resources and the insufficient supply of COVID testing packages and vaccination. The increased demand and the limited supply of healthcare and medical resources have reflected and even worsen racial and socioeconomic disparities.

Testing site is one important public facility in the prevention and protection of COVID-19. To access the testing sites, public transit provides people a convenient and effective given its large transportation volume, speed and punctuality. However, most transit facilities can also be accessed where population is more concentrated and socioeconomic activities are more active (Chen et al., 2017). Consequently, people living far away from the public transport will access the testing sites restrictively. Considering vulnerable groups, especially elderly, who suffer limited mobility or financial resources, health and policies planners should ensure that the access to COVID-19 testing sites is adequate and equitable across all socioeconomic factors (Duffy, Newing & Gorska, 2021; Tao et al., 2020).

Literature review

A plethora of studies have focused on the measurement of spatial accessibility to health care services. One commonly used method for measuring the spatial accessibility is the floating catchment (FCA) method proposed by Luo and Wang in examining the spatial accessibility to primary health care in Chicago (2003). Under the context of COVID-19, there are some modifications of FCA methods in the examination of accessibility to healthcare resources. The three-step floating catchment area (3FSCA) method is used to identify the spatial accessibility of COVID-19 patients in Florida (Kim et al., 2021). Considering the available hospital capacity and the average travel time to hospital, Escobar et al. (2020) used the enhanced two-step floating catchment area (E2SFCA) method to evaluate the current ICU supply in Manizales-Villamaría Metropolitan Area. One limitation of FCA-family method is that the demands, supplies, catchment size and spatial interaction functions are considered as static and fixed values. However, in the context of COVID-19, those variables are spatio-temporal changing. Without the consideration of fixed supply and demand capacities, another typical method that estimated the spatial accessibility is to establish the road network dataset to calculate the O-D travel time matrix (Wang & Wang, 2022). Silalahi et al (2020) created O-D Cost Matrix from the GIS-based network, where the nearest referral hospitals of the COVID-19 confirmed cases locations can be decided in Jakarta.

There are still some problems with regards assessing the spatial access to the health care facilities during the COVID-19 pandemic, where the demand for medical resources increased dramatically (Ghorbanzadeh et al., 2021). Many research focuses on the county level of accessibility measurement of a whole state (Kim et al., 2021). However, investigating a micro-level region, such as census tracts or block groups, will be more meaningful because in reality, people tend to travel across tracts rather than counties to access the

COVID-19 medical resources timely. In addition, most studies only considered one travel mode, especially driving, in the measurement of accessibility. But when accounting for a city, accessibility by different transit modes (personal vehicles, walking and public transit) should be analyzed and compared, since multimodal network is a fundamental component of a city that connects health facilities with people (Del Conte et al., 2022). Moreover, as many research has analyzed the relationship between confirmed cases and its influencing factors (Cordes & Castro, 2020), or between the medical resource distribution and demographic factors (Grigsby-Toussaint, Shin & Jones, 2021), very few studies explored the driven factors of spatial accessibility to medical resources, especially from a geographic perspective. Revealing the influencing factors of accessibility to healthcare facilities will help urban planners understand better about the cause of medical resources inequity and know how to utilize and allocate medical resources rationally.

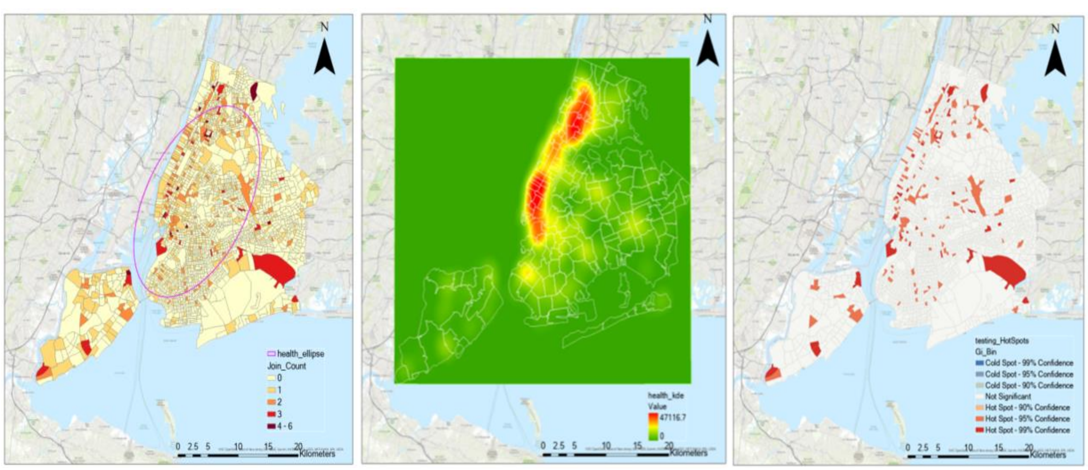
Motivation

Based on these challenges, this study focuses on the accessibility to the COVID-19 testing sites in NYC, which has a highly diverse population of 8.8 million people spread across five boroughs interconnected by bus and subway system (U.S. Census Bureau, 2021). Following three research issues are analyzed in this paper. First, the spatial clustering pattern of COVID-19 testing sites is identified through spatial autocorrelation and kernel density estimation methods. Second, spatial accessibilities over different census tracts in NYC are analyzed by four different transit modes, including walking, buses, subways or cars. Finally, Geodetector method is applied to identify the influencing factors, from socioeconomic and demographic aspects, of spatial accessibilities of testing sites. The goal of this study is to identify the disparities in accessibility to testing sites by different modes and the causes of such disparities, then provides guidance for future efforts in allocating testing resources in an equitable manner.

Current research progress

- the spatial distribution of COVID-19 testing sites

  With spatial autocorrelation analysis and kernel density estimation methods, the spatial clustering pattern of COVID-19 testing sites will be identified in Figure 1. According to (b), most of testing sites clustered at Manhattan. From (a) and (c), the spatial distribution of testing sites is uneven and the hotspots are randomly distributed. The Global Moran's I index is about 0.13 (P-value < 0.05), which confirmed that overall, the testing sites have a random distribution pattern in NYC.



(a) (b) (c)

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Figure 1. the spatial distribution of COVID-19 testing sites in NYC: (a) count of testing sites contained in each tract. (b) kernel density estimation of testing sites. (c) hotspots of testing sites

- the spatial accessibility of testing sites
  In the measurement of difference in spatial accessibilities by different modes, four common commuting patterns, including walking, driving, subway and bus, are compared based on the O-D cost matrix function of ArcGIS Network Analyst.
- non-transit accessibility: walk and drive
  Walking and driving are categorized into non-transit mode. Considering that for convenience, people will walk or drive to their nearest testing sites, this study will only measure the facilities within 15 minutes walking or driving from each census tract centroid. Typically, a more accessible census tract means that a greater volume of population, companied with more counts of closest facilities within a given range and less total time to arrive at the destinations. So the calculation of census tract i's accessibility can be measured as the following equation:

$$A_i=P_i*\sum_{n}^{0} 1/Ti \quad (1)$$

Where A_i is the accessibility of census tract i, P_i is the population number of census tract i, n is number of testing sites that people can access within a given region and T_i is the time people spend getting to each testing site. The accessibility of each census tract centroid is calculated and then IDW interpolation method is applied for spatial interpolation of accessibility in the whole NYC.

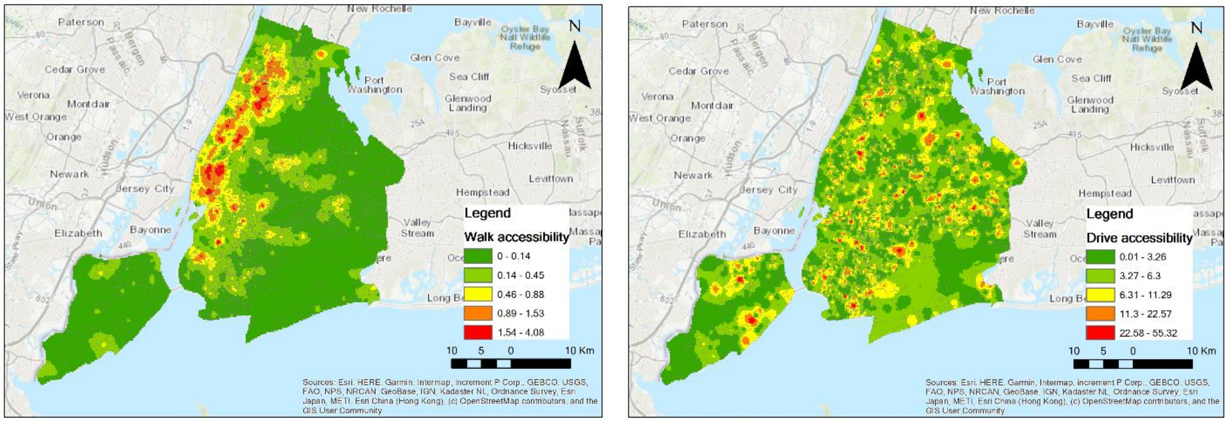
The road network for walking and driving were constructed from OSM dataset at first. Considering that people typically walk and drive on different roads of types, this study extract types of roads for pedestrians and drivers according to table 1. To calculate the accessibility as equation (1) shows, speeds of walking or driving on typical roads are decided in table 1, where 5km/h are set as the average speed people walk, while different speeds of driving are assigned according to the different road types. Different from building the pedestrian road network, some restrictions are included in the driving road network, such as one-way driving, delay of turning and traffic lights. Since the elevation of NYC is relatively flat, its impact on the walking or driving can be ignored.

Non-transit	Road type	Speed (mph)
walk	Footway, living street, path, residential, service, etc.	3.5
drive	Motorway	50
	Primary road	40
	Secondary	30
	Tertiary	25
	Residential	15

Table 1. road types and speeds of walking and driving

Figure 2 shows the spatial accessibility of walking and driving. Walk accessibility indicates a clustering distribution pattern, which is highest in Manhattan and decreases gradually to the edge. In contrast, the distribution of drive accessibility is random, with a few highest regions in Manhattan and Brooklyn and Queens. The accessibility enhances significantly from walking to driving, since ideally with driving, people can access to more testing sites within a shorter time.

However, in reality the driving accessibility will be less than this study shows, considering the traffic congestion and parking issues.



(a) (b)

Figure 2. the non-transit accessibility to testing sites within 15 minutes: (a) walking, (b) driving

- transit accessibility: subway and bus

  To evaluate how transit improves the accessibility, subways and buses, two dominant transit systems, are chosen and their accessibilities are calculated differently from the non-transit modes, since transit routes and schedules are fixable with given stops that travelers should take. The transit road network for subway and bus are built based on the GTFS data in Figure 3, using Conversion tools in ArcGIS Pro.

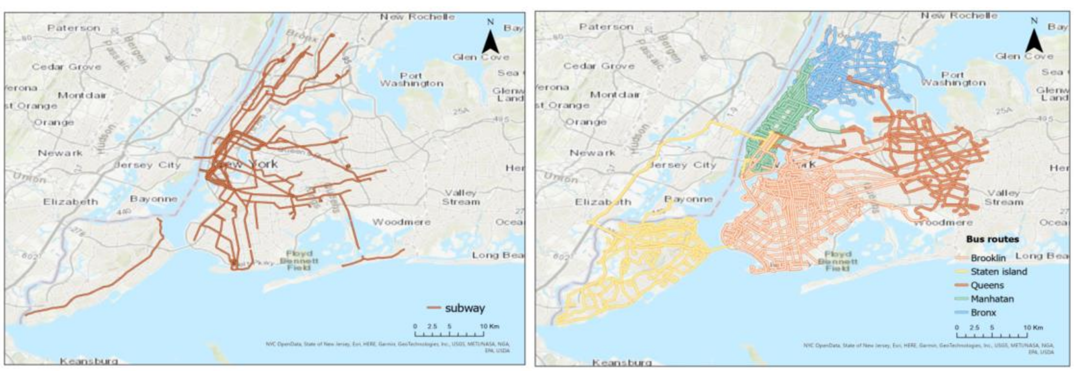


Figure 3. the subway and bus route system in NYC

Unlikely the non-transit road network, which set the population weighted centroid as the origins in the O-D cost matrix, subway or bus stops are set as the origins in the transit road network. The transit accessibility of each stop is calculated as the following equation and then the spatial interpolation of accessibility in the whole NYC is measured through IDW interpolation method:

$$Ai = \sum_{n}^{0} \frac{1}{Ti} \qquad (2)$$

Where n stands for the count of testing sites that can be reached within 15 minutes of taking the subway or buses, while Ti is the time people spend getting to each testing site starting from stop i.

The speeds of taking the subway and bus are set to 28km/h and 13km/h respectively. To build a comprehensive transit road network system, pedestrian road network is combined with the subway or bus route system in figure 3, since when getting off the nearest stops to the testing sites, people still need to walk for a while to reach their destination. In the combination of these road networks, the connection between pedestrian and subway or bus routes are built within the 50m buffer zones of stops so that people can switch from subway or bus modes to walk.

The transit accessibility is calculated in figure 4. Transit accessibility is highest in Manhattan and decreased gradually to the edge of NYC. Most regions are more accessible to subways than bus, since typically subways take shorter time to wait and hardly encounter traffic jam, despite that there are much more bus stations than subways in NYC.

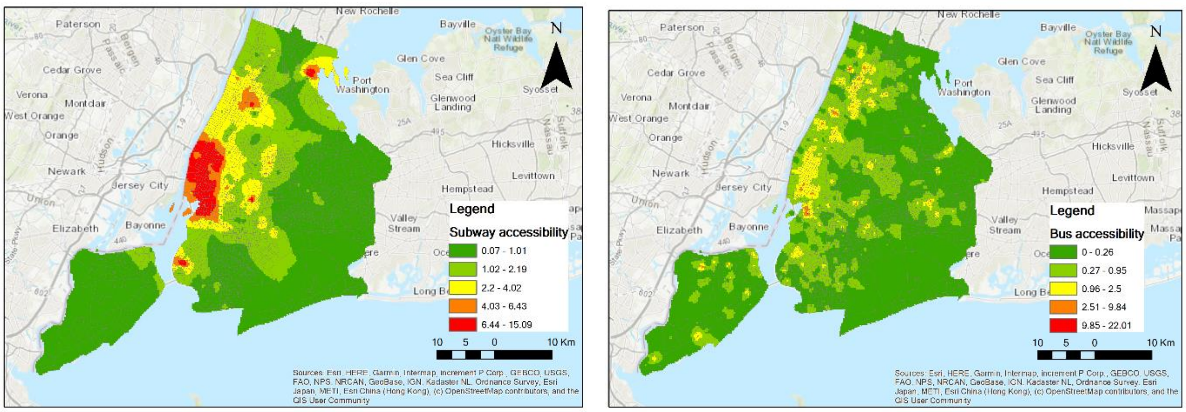


Figure 4. the transit accessibility to testing sites within 15 minutes: (a) subway, (b) bus

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