City-Cut or Radius-Cut? Design Principle of the Chinese Anti-pandemic Traveling Record Card System

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Abstract

Analysis of 25 million Shanghai citizens' daily movements supports the city-cut approach for travel restrictions in the early stage of the COVID-19 pandemic. The city's high connectivity and compact nature justify the city-cut approach over the geographic distance-based radius-cut approach, effectively containing the spread of COVID-19 within the metropolis.

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Abstract: *Analysis of 25 million Shanghai citizens' daily movements supports the city-cut approach for travel restrictions in the early stage of the COVID-19 pandemic. The city's high connectivity and compact nature justify the city-cut approach over the geographic distance-based radius-cut approach, effectively containing the spread of COVID-19 within the metropolis.*

Keywords: COVID-19; anti-pandemic traveling record card; city-cut design; people movement

For anyone who stayed or traveled in mainland China during the COVID-19 pandemic, the picture shown in Figure 1 is the essential identification card [1, 2]. It is called the *anti-pandemic traveling record card*, obtainable from a smartphone app. Briefly, it lists up (in the bottom lines) all the Chinese cities that an individual has stayed in or visited during the past 14 days. Cities that are considered as *row-risk* places (for COVID-19) will be in *black color*, while *medium/highrisk* places will be in *red color*. When an individual has a travel record (excluding the city of the present location) in red color (i.e., medium/high-risk), his/her entering request (hotel checkingin) might be rejected, or additional proof of health conditions might be requested.

Shanghai is a megacity in China with 16 districts, a population of 25 million, and a size of 6,000 square kilometers (Figure 2). It is surrounded by three other big cities (Suzhou, Nantong, and Jiaxing, a total of another 25 million people) The geographic distances between the 16 districts are heterogeneous (as far as over 100 km).

Several important questions arised from the design of the anti-pandemic traveling record card system. First, when one confirmed case is found in a district of Shanghai, should all the people in Shanghai, including those far away from the district, be labeled by the red color? Second, if the confirmed case is close to another neighboring city, should people in the neighboring city be labeled by the red-color, rather than the people in a far-away district of Shanghai? In other words, should the design principle of the anti-pandemic traveling record card system be *citycut* (defined by urban governance) or *radius-cut* (defined by geographical distance)? The city-cut strategy adopted by Shanghai during the pandemic has the clear advantage of easy management. However, to justify the legitimacy of the city-cut design, we need to find at least evidence that supports the following two hypotheses.

Figure 1: Chinese Anti-pandemic Traveling Card.

Figure 2: Map of Shanghai.

Hypothesis 1. *For the people in Shanghai, the frequency of intra-city movements (i.e., traveling inside Shanghai) is significantly higher than inter-city movements. This fact holds even for those whose living/working locations are close to the city-boundary lines.*

Hypothesis 2. *For the people in Shanghai, the intra-city long-distance movements are frequent. This fact holds even for those whose living/working locations are close to the city-boundary lines.*

In order to verify the above hypotheses, we obtained proprietary data from China Unicom (a major mobile service providers), covering all users in Shanghai during Oct 10 - Nov 24, 2019 (before the outbreak of COVID-19) and Oct 10 - Nov 24, 2020 (when China resumed from the early outbreak) during the pandemic.

We define four types of movements: *Intra-city (Intra)*: movement between two grids or within

one grid in Shanghai. *Inter-city (Inter)*: movement from Shanghai to another city. *Intra-city-long-distance (Intra ld)*: movement between two grids in two nonadjacent districts of Shanghai. *Intra-city-to-center (Intra tc)*: movement to a gird in city-center districts of Shanghai. Please refer to the **Method** section for modeling details.

Tables 1-2 show the statistics of different types of movements made by people in Shanghai during Oct 10 - Nov 24, 2019. Table 1 reports the proportions of the four types of movements over all movements, for all the sixteen districts of Shanghai (with standard errors in parentheses). Table 2 reports the results for all city borders in different districts.

From the two tables, we have the following findings. First, for all districts of Shanghai, the frequency of intra-city movements is significantly higher than that of inter-city movements. Second, there are frequent intra-city-long-distance movements across all districts. Third, the frequency of intra-city-long-distance movements is greater than that of inter-city movements. The *p*-value of the two proportions to be equal is less than 0.01, for any district. Fourth, intracity-to-center movements are frequent across all districts. This result indicates that people from all districts can be well mixed in city centers. Thus, it is highly possible for the disease to be transmitted from a (remote) district to city centers and then to the whole city. Fifthy, the main results above also hold for the city borders. The only exception is for the Chongming city border, a special district on an island that partly belongs to another city (Nantong) as well.

To summarize, both hypotheses are supported. We see the strong “connectivity” of Shanghai in the sense that all districts and areas, including city borders, are well connected in terms of daily people movements. In addition, Shanghai, similar to other megacities of China, has the natural feature of “compactness,” such that inter-city movement is significantly less frequent than intra-city movement [3]. These findings justify the legitimacy of the *city-cut* design of the anti-pandemic traveling record card system in the early stage of the pandemic.

District	Intra	Inter	Intra ld	Intra tc
Baoshan	98.2% (0.002)	1.8% (0.002)	14.8% (0.011)	15.2% (0.008)
Changning	98.0% (0.006)	2.0% (0.006)	24.3% (0.006)	18.6% (0.005)
Chongming	93.7% (0.003)	6.3% (0.003)	11.2% (0.012)	3.9% (0.006)
Fengxian	99.0% (0.001)	1.0% (0.001)	4.7% (0.005)	3.3% (0.003)
Hongkou	98.5% (0.007)	1.5% (0.007)	15.1% (0.012)	19.3% (0.013)
Huangpu	98.5% (0.004)	1.5% (0.004)	23.4% (0.006)	18.0% (0.007)
Jiading	95.0% (0.003)	5.0% (0.003)	10.7% (0.004)	11.4% (0.008)
Jingan	98.5% (0.004)	1.5% (0.004)	19.5% (0.006)	19.0% (0.008)
Jinshan	94.7% (0.002)	5.3% (0.002)	9.9% (0.007)	3.5% (0.005)
Minhang	97.6% (0.004)	2.4% (0.004)	10.7% (0.008)	13.1% (0.010)
Pudong	98.1% (0.002)	1.9% (0.002)	10.1% (0.005)	10.1% (0.009)
Putuo	96.4% (0.007)	3.6% (0.007)	21.5% (0.012)	18.6% (0.011)
Qingpu	91.8% (0.002)	8.2% (0.002)	13.3% (0.004)	8.2% (0.004)
Songjiang	98.2% (0.002)	1.8% (0.002)	11.4% (0.007)	7.1% (0.005)
Xuhui	98.7% (0.002)	1.3% (0.002)	17.2% (0.009)	19.0% (0.012)

Yangpu	99.0% (0.003)	1.0% (0.003)	18.1% (0.012)	18.8% (0.012)
City Average	97.2% (0.003)	2.8% (0.003)	13.7% (0.006)	12.6% (0.008)

Table 1: Movement Analysis for Shanghai Districts (Oct 10 - Nov 24, 2019)

These results remain valid for the data in 2020 (refer to the Online Supplement).

We also performed further clustering analysis to examine if we may derive an effective *district-cluster-cut* strategy to confront the pandemic. Following the Markov transition matrix method [4, 5], we identify 16 clusters of grid units (Figure 3) based on their movement patterns. We find that the areas of the clusters (colors) do not coincide with the locations of the districts (red borders). Thus, district-cut strategy may not be practical for the anti-pandemic traveling record card system in Shanghai during the early stage of the pandemic.

In conclusion, this study provides a comprehensive analysis of the daily movements of individuals in Shanghai, utilizing proprietary data from China Unicom. With over 1.44 billion instances of individual movements recorded, our findings offer unprecedented insights into the ”connectivity” and ”compactness” of urban populations, which are crucial for informing public health policies. The study’s implications extend beyond the immediate pandemic response, offering a framework for future travel-related disease containment strategies. The comparison between the ”city-cut” and ”radius-cut” identification principles for travel restrictions presents a novel approach to understanding and managing the spread of infectious diseases in densely populated areas.

Area	Intra	Inter	Intra ld	Intra tc
Baoshan city border	92.0% (0.004)	8.0% (0.004)	10.8% (0.005)	5.3% (0.005)
Chongming city border	84.6% (0.010)	15.4% (0.010)	12.3% (0.014)	4.2% (0.008)
Jiading city border	91.4% (0.004)	8.6% (0.004)	10.3% (0.005)	8.9% (0.004)
Jinshan city border	93.3% (0.003)	6.7% (0.003)	11.4% (0.008)	4.1% (0.005)
Qingpu city border	90.7% (0.004)	9.3% (0.004)	10.3% (0.005)	5.7% (0.003)
City Average	91.0% (0.003)	9.0% (0.003)	10.8% (0.006)	6.1% (0.003)

Table 2: Movement Analysis for Shanghai City Borders (Oct 10 - Nov 24, 2019).

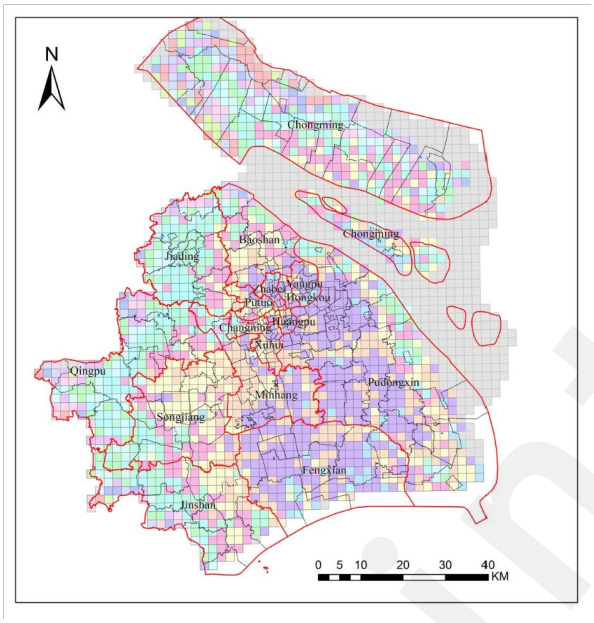

Figure 3: Clustering for Shanghai based on the movement patterns.

Author Statements: All authors have equal contributions to the study

Conflict of Interest: None

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Author Contribution: All authors contributed to conceptualization, data curation, formal analysis, methodology, visualization, writing—original draft, and writing—review and editing.

Methods

Our data is provided by China Unicom, covering all users in Shanghai during Oct 10 - Nov 24, 2019 and Oct 10 - Nov 24, 2020. Our data records the real-time locations of individual smartphones (identified from the base radio station connection records), from which we can restore detailed daily movements of individuals.

We considered the following modeling settings: (a) The map of Shanghai is divided into 2213 units of 2 km × 2 km grids. (b) If a person continuously stays in a grid for more than 30 minutes, then we consider that this person has a *visit* to this grid. (c) The data is being updated daily. In total, we obtained 1.44 billion times of individual movements. Here, we present results from the data in 2019. Results from the data in 2020 can be found in the Online Supplement. We define four types of movements:

- *Intra-city (Intra)*: movement between two grids or within one grid in Shanghai.
- *Inter-city (Inter)*: movement from Shanghai to another city.
- *Intra-city-long-distance (Intra ld)*: movement between two grids in two nonadjacent districts of Shanghai.
- *Intra-city-to-center (Intra tc)*: movement to a gird in city-center districts of Shanghai (i.e., the seven small-size and centrally-located districts including Changning; Hongkou; Huangpu; Jingan; Putuo; Xuhui; and Yangpu).

To study the movements of people whose living/working locations are close to

neighboring cities, we define *city borders* to be the areas that are inside the boundary districts of Shanghai (i.e., districts sharing boundaries with neighboring cities) and within an 8-km distance from the city-boundary lines of Shanghai.

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Supplementary Files