9^{th} International Conference on Computational Social Science IC^2S^2
July 17-20, 2023, Copenhagen, Denmark

Mobility and transit segregation in urban spaces.

Human Mobility, Transit Networks, Segregation, Socioeconomic Inequality, Transport Poverty

Extended Abstract

The ability for individuals to move throughout a city creates opportunities for reducing the impact of social and economic disadvantages. By facilitating movement within urban areas, transit systems can democratize accessibility to resources and opportunities, while also fostering social integration and interactions among individuals from different areas and/or sociodemographic backgrounds. Conversely, inequalities in transport services can hinder individuals from fulfilling their travel demands [1]. In this work, we explore socioeconomic segregation in cities from the perspective of their transit systems and how they interact with the other layers of the urban segregation landscape.

Recently, research in segregation has extended from strictly the residential perspective to consider how segregated regions are based on the population that visits it [2]. Other works have also leveraged mobility networks to quantify how segregated mobility patterns are [3]. We build upon these nuanced, dynamic approaches of measuring segregation, to better understand how inequality can be experienced in the different facets of the urban experience.

In our analyses, we leverage amenity visitation patterns from anonymized mobile phone traces provided by SafeGraph, to estimate the mobility flows between areas (i.e., Census Block Groups - CBGs) in a given city. We define the economic composition of each CBG in a city, using the 2020 American Community Survey (ACS) to inform the CBG's population distribution across 20 income categories. For 15 US cities, we retrieve General Transit Feed Specification (GTFS) and OpenStreetMap (OSM) data to construct transit-pedestrian networks. The transit pedestrian networks reveal what transit lines an individual would use to travel between any two pairs of points using public transportation. Thus, by combining the volume of mobility flows between block groups, the respective economic breakdowns of trip origins, and the transit-pedestrian networks, we can estimate the socioeconomic composition of different public transport routes within a city.

We compute two dimensions of experiential segregation (ES) for a given neighbourhood: the ES at the amenities its residents visit (**Destination Segregation**) and the segregation its residents experience while using the transit system to reach said destinations (**Transit Segregation**). We estimate economic segregation using the Index of Concentration at the Extremes (ICE), which ranges from -1 to 1, reflecting extreme concentration of individuals from the 20th and 80th income percentile, respectively [4]. For the sake of completeness, we also measure ES using two other segregation metrics: the Index of Dissimilarity and Local Entropy. However, we focus on the results using the ICE, due to its ability to distinguish between the segregation of privileged and under-privileged groups. Thus, Destination Segregation can be calculated using the empirical mobility flows between CBGs that is derived from the SafeGraph data. Meanwhile, Transit Segregation is measured through a stochastic process, in which we perform a weighted sampling of individuals travelling from each CBG, defining individuals' economic profiles with respect to their CBG's population distribution across income brackets. Thus, Figure 1 visualises how segregated each edge in the transit network would be, over 100 iterations, with the assumption that every income group uses the transit system with equal probability. However, our stochastic approach to measuring transit use allows us to test different assumptions pertaining to which economic groups are likely to use the transit system.

Our findings suggest that the segregation experienced while using the transit system is reflective of an underlying inequality in a city's transport service. For each city, we split CBGs, according to their median income (from the ACS), into five, equally sized income groups. Panel A in Figure 1 reflects disparities in segregation for the lowest and highest income groups, when considering the residential and transit dimensions. The green and orange circles illustrate a fairly trivial point, that CBGs with low median incomes have more concentration of low-income residents than CBGs with high median income levels. However, comparing the distribution of transit segregation highlights how socioeconomic inequality also exists in the public transportation dimension. That is, for low income CBGs, the social exposure within the transit system is more concentrated with lower income residents than compared to the high income CBGs. We reiterate that these disparities are identified in the scenario where individuals, regardless of their socioeconomic background, have an equal likelihood of travelling by public transit.

We compare our empirical results, seen in Panel A, to the measured segregation of a null model, which hypothesises that destination segregation is what fuels the identified disparities in transit segregation across income groups. We implement the null model by rewiring the mobility network such that destinations are uniformly sampled from all CBGs in the city. Furthermore, we address the potential sampling bias in the SafeGraph data by fixing the number of outgoing trips across all areas. Panel B in Figure 1 elucidates how the identified transit segregation is not solely an artefact of destination segregation by comparing empirical results to that of the null model, in which levels of destination segregation converge to reflect the city's economic composition. That is, the transit network layout exhibits features that enable segregation to spill over from the residential facet of urban life. Moreover, while segregation still exists in the transport and destination dimensions, Panel B conveys how the individuals are exposed to the highest magnitudes of segregation in the residential dimension, with destination and namely transit segregation allowing for potential avenues for reducing experiential segregation.

This work identifies how socioeconomic inequalities are encoded into the structure of transit networks. Moreover, this study aims to motivate developments in urban planning to address segregation from beyond the residential dimension. Ultimately, by identifying how transit infrastructure may perpetuate segregation, we pursue the first of many steps to reimagining transport as a public space and a point of inclusion within the urban realm.

References

[1] Leonardo Nicoletti, Mikhail Sirenko, and Trivik Verma. Disadvantaged communities have lower access to urban infrastructure. *Environment and Planning B: Urban Analytics and City Science*, 2022.

[2] Hugo Barbosa, Surendra Hazarie, Brian Dickinson, Aleix Bassolas, Adam Frank, Henry Kautz, Adam Sadilek, José J Ramasco, and Gourab Ghoshal. Uncovering the socioeconomic facets of human mobility. *Scientific reports*, 11(1):8616, 2021.

[3] Jennifer Candipan, Nolan Edward Phillips, Robert J Sampson, and Mario Small. From residence to movement: The nature of racial segregation in everyday urban mobility. *Urban Studies*, 58(15):3095–3117, 2021.

[4] Alan Booth and Ann C Crouter. The prodigal paradigm returns: ecology comes back to sociology. In *Does it take a village?*, pages 53–60. Psychology Press, 2001.

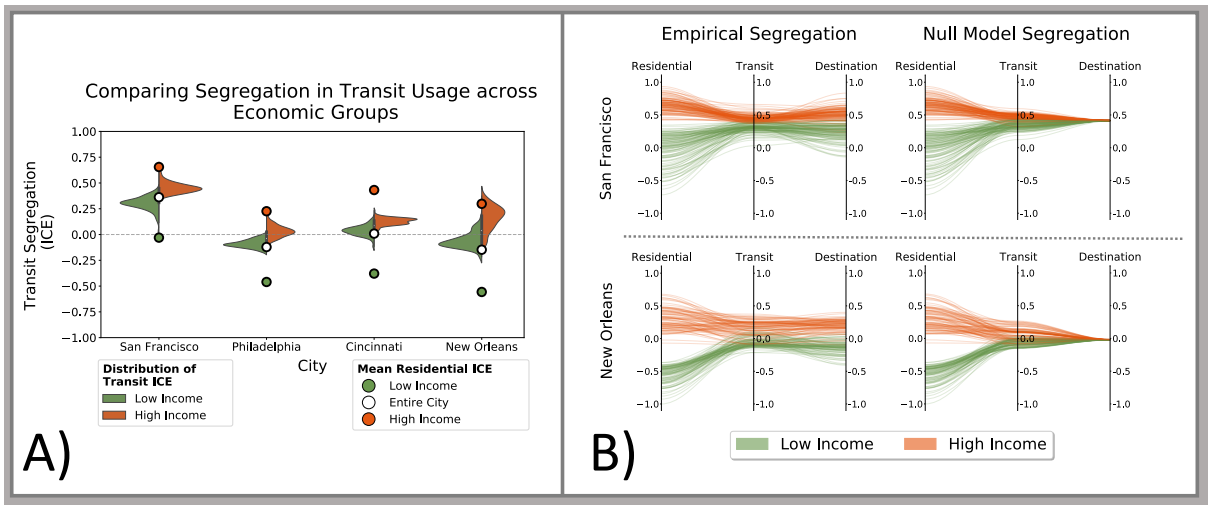

Figure 1: Panel A illustrates the distributions of ES in the transit system for low and high income CBGs across 4 cities, with -1 and +1 indicating extreme concentration of the low and high income group, respectively. The points reflect the mean residential segregation considering neighbourhoods in the lowest quintile, highest quintile, and the entire city. Panel B, compares CBG-level segregation across the residential, transit and destination dimensions for San Francisco and New Orleans. Comparing the changes in ES, between the empirical data and the null model, highlights how transit segregation exists regardless of the degree of destination segregation in a city.