



UNVEILING SOCIOECONOMIC DIFFERENCES IN COLOMBIA BY MEANS OF URBAN MOBILITY COMPLEX NETWORKS

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ABSTRACT

Social stratification lead to marked differences between people in several aspects of their lives, such as income, education, work, welfare and mobility. Here, we aim to analyze urban mobility by socioeconomic differences of travelers. In order to do so, we represent urban mobility by a complex network approach. We show that the topological properties of the networks allow to characterize mobility flows and to recognize differences in the dynamics of socioeconomic strata. We use data from origin destination surveys made for the two most populated cities in Colombia and we represent it in the form of a weighted and directed network. We found that urban mobility networks have structural differences if analyzed by socioeconomic strata of the population and unveil segregation patterns in the highest and lowest income strata.

Keywords.

Urban mobility; Socioeconomic segregation; Complex networks



Introduction

Understanding socioeconomic differences is of crucial importance to fight inequity, which is one of the main socio-political problems of Colombia. Under Laws 142 and 143 of 1994, there was designed a system that classifies housing into six socioeconomic strata according to the characteristics of housing and the utilities paying capacity of the household. Strata 1 to 3 have subsidized utility bills; stratum 4 pays the marginal cost of the utilities, and strata 5 and 6 pay more to subsidize the other strata. Although socioeconomic stratification was designed for housing, it has been widely used as a proxy of households income level and wealth status, being those in status 1 the poorest and those in status 6 the richest (Medina, Morales, Bernal, & Torero, 2007).

Also, understanding of urban mobility is crucial for urban planning, policy and decision making. A natural way for representing urban mobility is by mapping into graphs the different places or spatial zones of the city and the fluxes of people between them. This representation supports the analysis of complex networks (Newman, 2010), that has garnered the interest of researchers from several disciplines as it gives information about complex systems made of many interacting parts or elements. The fundamental insight from complex network analysis is that large-scale networks are characterized by properties of the system as a whole rather than by the individual properties of nodes and edges (Amaral & Ottino, 2004; Newman, 2010).

Here, we tackle the issue of the network topology and the relationship between socioeconomic composition of the population in a city and its relationship with urban mobility. We analyze the urban mobility of Bogota and Medellin metropolitan areas, in Colombia, using data from origin-destination surveys and segment the analysis by the socioeconomic strata of the travelers, in order



to make comparisons between urban mobility of populations with different income levels.

Urban mobility complex networks

Network analysis provides the foundations for representing the interactions between spatial domains of a city in terms of the travel patterns of people (De Montis et al., 2007; De Montis, Caschili, & Chessa, 2013). The analysis of urban mobility using data from origin-destination surveys can be done by representing the spatial partition of the city in zones and the fluxes of people from an origin to a destination zone by a simple, directed and weighted network. The centroids of the origin-destination zones are mapped into the set of nodes N , and the fluxes into the set of weighted links W ; each link going from node i to node j has weight w_{ij} and represents the amount of trips between origin zone i towards destination j . The resulting network can be represented as a weighted and directed graph $G(N,W)$. From the weighted network represented by the matrix W we obtain the adjacency matrix A with entries a_{ij} that take binary values (0/1) providing information about the existence or not of any trip from zone i to zone j .

In Figure 1 we present the map of the mobility hotspots for each socioeconomic status. The nodes are sized by its nodal degree. We show the upper interval in a Jenks natural breaks classification with two classes for each socioeconomic status. Similarly, in Figure 2, we present the map of urban mobility by strata in Medellin. In those maps, it is possible to identify the higher strata householders (namely 5 and 6) are located and move to limited parts of the city, while strata 2, 3 and 4 move around the city covering almost the whole area in both cities. Status 1 in Bogota is more constrained to the south part of the city, while in Medellin is distributed in five clusters: the center and some hillside of the valley.

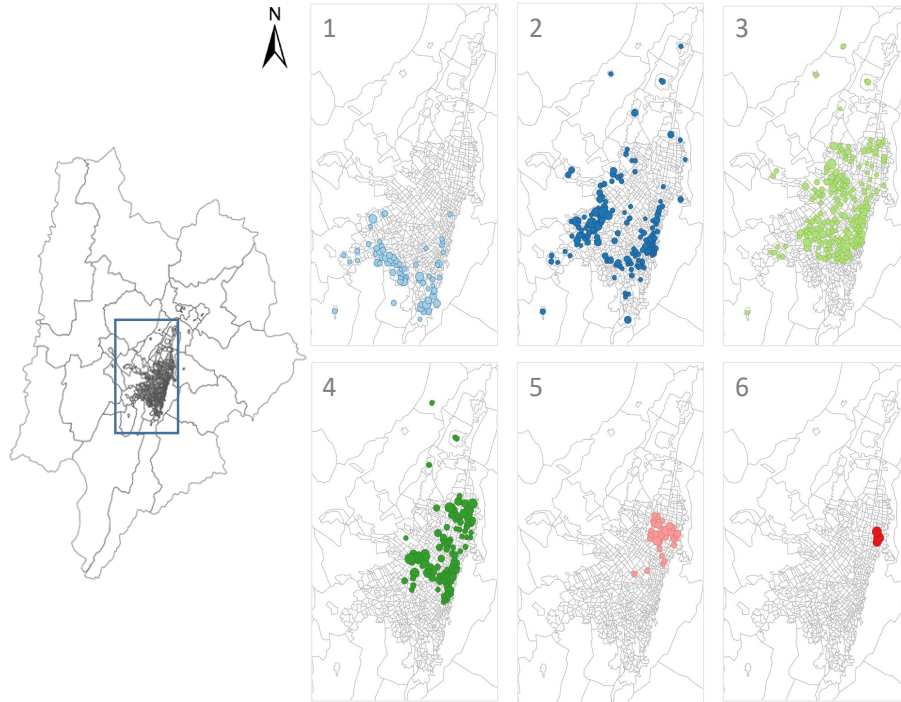


Figure 1 Map of the zones with higher nodal degree by socioeconomic strata in Bogotá

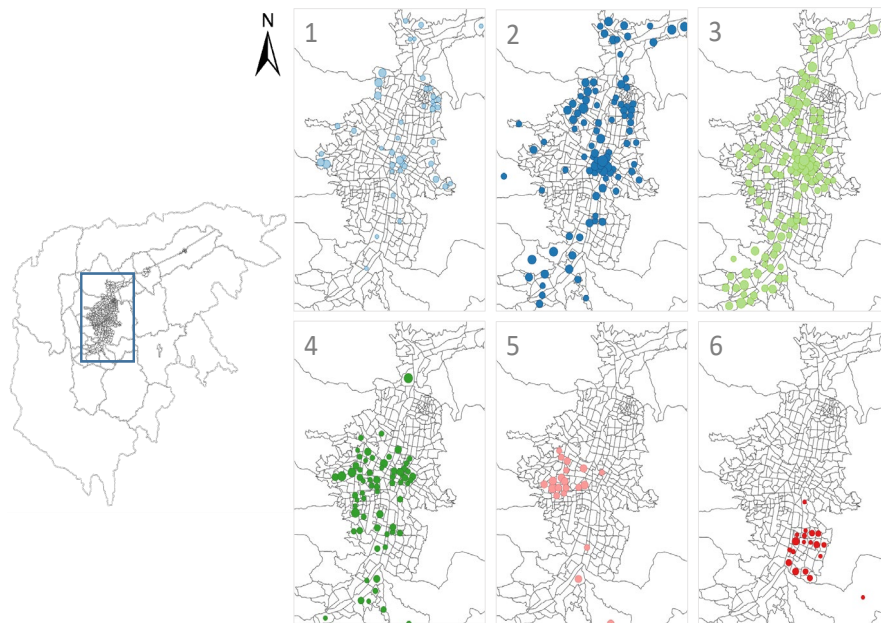


Figure 2. Map of the zones with higher nodal degree by socioeconomic strata in Medellín



The networks formed by the mobility of people belonging to strata 2 and 3 covers most of the city (more than 90% of the city in terms of number of zones visited), while the networks of people of the highest socioeconomic status only show that they visit 31.6% and 47.2% of the zones in Bogota and Medellin, respectively. With the number of nodes of each network, we can identify that people of high-income (strata 5 and 6) move selectively in few parts of the city and people of low to medium socioeconomic status move around the city.

Discussion

Spatial segregation is a common feature of metropolises and it can be related to ethnic, religion or socioeconomic groups. In our study, we analyzed the spatial segregation related to income by considering the urban mobility patterns of different socioeconomic strata.

We found that people from higher socioeconomic strata move in a very specific and constrained zones of the city. We interpret this result as a consequence of the ease for this group of people to locate according to their preferences and convenience, which in turn can improve their mobility patterns. The second group of people, which refers to medium and medium-low strata are located and move through most of the zones of the cities analyzed, and it is a consequence of the tradeoff between their paying capacity for a price-accessible housing and the location of their activities. Finally, the group composed by the lowest income households is constrained to move in limited zones of the city. We relate this result to the budget constraints of this people to buy or rent housing in well-connected zones and to the lack of possibilities to access most of the transportation means due to its cost and therefore the difficult to access distant zones to their homes in the city.

In a related work (Loterio et al 2016) we introduced a multiplex approach for each socioeconomic group, by including transportation modes as layers of the network. We found that transportation modes and socioeconomic status are



mobility variables that are highly related. We found that extreme socioeconomic strata (highest and lowest) are less multimodal and more segregated in their mobility patterns, while mid-low strata (2 and 3) are less spatially segregated in terms of mobility and tend to use more transportation modes.

Although it is difficult to identify whether the segregation is a cause or an effect of socioeconomic differences, policy makers should consider these results in order to try to mitigate the negative consequences of socioeconomic segregation. These negative effects include a sense of insecurity (in low-income strata zones) and the distortion of land and housing markets (in high-income strata zones), among others. Our results give insights to urban planners to prioritize zones or groups of people in order to make urban mobility plans or interventions to incentive a multimodal mobility or to mitigate the spatial and socioeconomic segregation.

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