Productive exclusion: Accessibility inequalities and informal employment in Bogotá

Informal employment and accessibility inequalities:

Productive exclusion in Bogotá

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Abstract

Public transport provision has historically been biased against less affluent neighbourhoods, making access to jobs more costly and difficult for a substantial segment of the low(er)-income population. Our research explores the distribution of accessibility to formal and informal employment in Bogotá, Colombia. Building on geocoded travel and household characterisation data for the city and potential accessibility metrics, we present evidence of the contribution of public transport to social and spatial inequalities in accessibility for individuals in different spatial, economic, and social categories and the resulting mobility and accessibility inequalities such a distribution entails. Our analysis draws on social and economic inclusion, linking accessibility to and by public transport to the degree to which individuals are included in the safety nets associated with formal employment. We interrogate the effects of the current configuration of Bogotá and its public transport networks on improving accessibility to quality job opportunities, interpreting higher dependency from informal jobs as productive exclusion. Our study combines two perspectives not often combined, identifying variable levels of social and productive inclusion within the population. The findings suggest that progressive investments in bus rapid transit (BRT) and other forms of public transport around high-demand and highly attractive corridors reinforce cycles of segregation and concentration of formal and informal economic activities. We provide empirical evidence that can contribute to design and target policies for low-skilled and low-income workers in the informal economy.

Keywords: accessibility; informality; exclusion; inequality; public transport

1. Introduction

There are over 2 billion people worldwide in informal employment in 2023, with 241 million workers living in extreme poverty (ILO, 2024, p. 29). According to Giuliano et al. (2015), the informal economy can generally be defined as the part of the economy where activities take place beyond official recognition and record. Common informal economic activities may include small scale enterprises and trade, self-employment, street vending, garbage recycling ventures, subcontracting, and unregistered home-based work. Such activities in the informal economy commonly share a lack of job security, access social protection and fair wages (Günther and Launov, 2012). The conceptual and statistical definition(s) of the informal economy remains widely debated in policy and practice (Alter Chen, 2012; Dell'Anno, 2022; Luque, 2021; Vanek et al., 2014).

In Latin America and the Caribbean (LAC), it is estimated that half of the working population is employed in the informal economy as of 2022 (ILO, 2022). The informal sector consisted of 38.6% in wage employment, 10.9% in household wage employment, and 41.4% in self-employment (Abramo, 2012). Workers in LAC region were significantly impacted by the COVID-19 pandemic with the region experiencing an estimated 16.2% reduction in work hours (during 2020 in comparison to 2019), nearly double the global estimate of 8.8% (Maurizio, 2021). The International Labour Organization (ILO) estimates that approximately 47% of the working population in Colombia is employed in the informal economy (ILO, 2023). On the other hand, the Organisation for Economic Co-operation and Development (OECD) estimates that over 60% of workers are employed in the informal sector (OECD, 2022).

The limited supply of local employment in informal and low-income settlements, and urban economies centred on the services sector (Botero and Suárez Espinosa, 2010), has led low-income and other socially disadvantaged populations to work in the informal economy. In cities across Latin America, the spatial distribution of work opportunities benefits more affluent population groups (García-López and Moreno-Monroy, 2016; Lopes Pinto et al., 2023), generating further disadvantages for low-income citizens to participate in the economy (Guzman and Bocarejo, 2017). In Bogotá, the capital city of Colombia, large jobs-housing imbalance in low-income zones means that individuals spend a lot of time on their commute to access work (Guzman et al., 2017b). Furthermore, informal employment tends to be irregular and can involve variable locations and constantly changing travel patterns that may increase travel costs and so reduces disposable income for addressing education, health, and other essential needs for human development. There is a strong relation between formality and informality determined by constant 'transactions' in terms of spatial, economic and social relationships that mark the notion of informality as a system that is not external to formal systems, but that is instead a consequence of formal structures, and that is usually strongly related to accepted formal set of rules and settings (Porter et al., 2011).

This paper analyses the relationship between informal employment, transport accessibility, as well as social and productive inclusion, and it asks: *What are the links between transport provision and accessibility to formal and informal employment of individuals experiencing different levels of exclusion?* Social and productive inclusion are understood, within the scope

of this paper, from the perspective of access to social safety nets and participation in the formal job market. We analyse Bogotá as an example of segregated and unequal urban environments in the Global South, where structural conditions for access can disproportionally affect more socially vulnerable populations. Bogotá is a city marked by socio-spatial segregation of the population and centralisation of economic opportunities, with nearly half its labour force working in the informal economy. We depart from definitions of accessibility and social and productive exclusion to explore the hypothesis that informal, and often poor, workers are systematically excluded—or at least less prioritised—by a transport and urban systems that privileges access and connectivity to formal employment and formal labour force. Such urban and transport configuration leads to inequalities in accessibility between formal and informal workers that can increase social disadvantage and poverty. Our paper contends that by differentiating between formal and informal labour opportunities, accessibility analysis can be enriched in relation to the understanding of transport's contribution to participation in the economy in cities such as Bogotá and the reproduction of systematic inequalities by the way we plan and prioritise public transport.

We build on the definition of accessibility as "the ease of reaching desired destinations given a number of available opportunities and intrinsic impedance to the resources used to travel from the origin to the destination" (Bocarejo and Oviedo, 2012, p. 143). The paper approaches formality and informality as a continuum rather than a dichotomy, unpacking some of the mechanisms by which formal and informal practices have contributed to inequalities in the key determinants of accessibility, that is, land-use, transport and communication, temporal, and individual and household characteristics (Geurs and van Wee, 2004). For instance, when examining where people live, the spatial coexistence of formality and informality is segregated, with informal and low-income housing restricted to the urban peripheries (Oviedo and Titheridge, 2016; Torres Arzayús and García Botero, 2010). By contrast, informal and formal economies in Bogotá often coexist in the same physical space, with many informal jobs being virtually indistinguishable from formal jobs (Günther and Launov, 2012; Williams and Lansky, 2013). Considering these conditions, we explore the distribution of accessibility to formal and informal employment in Bogotá, seeking to raise evidence of the contribution of public transport to social and spatial inequalities in accessibility for individuals with different social, economic and spatial characteristics deeply associated with different forms of informality.

Research on transport and social exclusion, in particular when applied in Global South urban contexts, commonly interpret exclusion as a consequence of reduced accessibility to opportunities that results from the intersections between transport and social disadvantage (Jaramillo et al., 2012; Lucas, 2019, 2012; Oviedo and Titheridge, 2016; Pucci and Vecchio, 2019; van Wee and Geurs, 2011). This study engages with these discussions about what exclusion related to transport entails, while making an explicit recognition of the role of informality in shaping levels of disadvantage and its close relationship with poverty and other forms of informality. In this context, although the paper recognises that transport and access alone are not sufficient to guarantee access to formal employment, the analysis of the spatial distribution of formal and informal employment opportunities, their demand, and the configuration of the urban transport system in the city, can shed light on the ways in which

transport contributes to structural inequalities in access that further exclusion of informal workers.

Concerns about social and productive exclusion and the role of transport—particularly public transport—in increasing or hindering people's ability to maintain livelihoods in the formal and informal economy are essential for increasing transport equity. In the context of the COVID-19 pandemic, such concerns about accessibility for workers in the formal and informal sector became even more relevant (Cabezas et al., 2020; Gutiérrez et al., 2020; Maurizio, 2021). As millions of workers in the informal sector in Latin America faced the choice between exposing themselves and their families to the risk of infection and maintaining their livelihoods, understanding their mobility and spatial patterns and the role of public transport in enabling access could have better informed a rapidly changing urban transport policy to improve decision-making to reduce already large inequalities in accessibility between income groups and formal and informal workers. Looking forward, the analysis in this paper bridge current gaps between labour and accessibility research, giving greater recognition to the dynamics of access to employment in contexts where informality remains the choice for economic activities of a large share of the urban population.

The rest of the paper is structured as follows. Section 2 describes the main concepts framing the analysis. Section 3 presents a brief overview of Bogotá. Section 4 presents our methodology. Section 5 summarises the results and Section 6 our conclusions.

2. Framework

2.1.Defining labour informality

Informality is a global phenomenon with livelihoods of the poor in emerging market and developing economies (EMDEs) depending disproportionately on informal economic activity (Elgin et al., 2022). Development challenges associated with widespread informality includes extreme poverty, poor public infrastructure, and weak healthcare and sanitation systems (Ohnsorge and Yu, 2022). The motivations for informal economic activity can be grouped into four categories in existing literature (Elgin et al., 2022, p. 49-50). First, some workers and firms are 'excluded' from the modern economy and/or state systems due to burdensome regulations and the lack of human capital while other workers voluntarily 'exit' the formal sector and choose the informal sector for its flexibility and lower regulatory compliance (*ibid.*). Second, the persistence of low-skilled and low-productivity work with income that falls below subsistence levels (*ibid.*). Third, the lack of regulation, resulting in 'outsider' firms, as well as the lack of enforcement, resulting in 'evader' firms that do not comply to regulations and 'avoider' firms adjust to be outside the remit of regulations (*ibid.*). Fourth, the common practice of firms not registering their business or registered firms hiring workers 'off the books' (*ibid.*). Despite such reasoning, informality involves social costs such as lack of social security, low productivity and tax evasion, prompting both national governments and international development organisations to brand informality as a problem to be solved (Loayza, 2018; Oviedo et al., 2009).

The National Administrative Department of Statistics of Colombia (*Departamento Administrativo Nacional de Estadística*), hereafter DANE, considers a worker to be 'informal' when they work in establishments, companies, firms, or businesses with five or less people (Perfetti et al., 2017). Such definition allows for unpaid work, as long as the worker remains in a family business. As for independent workers, DANE's definition only considers those with formal higher education to be formal workers (*profesionales independientes*) (*ibid.*). DANE's definition also exclude all public sector employees from the informal sector. This aligns with the ILO's agreed definition during the 15th International Conference of Labour Statisticians (ICLS) (ILO, 1993), as well as the United Nations Statistics Division Delhi Group's guidelines (Guataquí et al., 2010). However, DANE's definition is very limited when defining informality. A firm's size is more related to its productive structure, rather than with the quality of jobs it offers, failing to differentiate small, formal production units such as small and medium enterprises (SMEs) from informal work.

Guataquí et al. (2010) propose an alternative methodology to measure informality in Colombia, which considers a 'strong' and a 'weak' definition that highlight issues of precarity and irregularity as key features of informal work (Hussmanns, 2004a, 2004b). The 'strong' definition includes all employed workers that: (i) own and pay for healthcare (and not dependent on a family member), (ii) have pension coverage or are pensioners, (iii) have secured a written employment contract, and (iv) earn more than 95% of the minimum wage (Guataquí et al., 2010). The 'weak' definition considers the minimum level of social protection that a worker must receive to guarantee their immediate and sustained availability to work. The 'weak' definition uses healthcare access as a precondition to ensure an individual's ability to work, considering a formal worker that who has and pays for their healthcare. This paper uses Guataquí's et al. (2010) definitions of informality in a slightly modified fashion—'strong informality' is considered without including the criteria of minimum wage as information about household and individual income is unreliable in available datasets. All non-paid workers are therefore also considered informal workers. The 'strong' definition of informality in this paper considers formal workers as paid employees who: (i) have and pay for healthcare, (ii) have a written employment contract, and (iii) are either affiliates of a pension fund or pensioners. For independent workers, the requirement of a written contract is not relevant when assessing their formality status. We also use Guataquí's et al. (2010) 'weak' definition, including all unpaid jobs as informal. Using these categories, an employed person can be defined as either formal or informal, and within the spectrum of informality, they can be considered as a 'weakly informal', or 'strongly informal' worker.

2.2.Accessibility, social and productive exclusion

Access to employment is a recurrent issue in transport studies. Both conceptual and empirical research has pointed towards links between accessibility to employment, poverty, and social exclusion (Jaramillo et al., 2012; Kaltheier, 2002; Levine, 2020; Moreno-Monroy, 2016; Stanley and Lucas, 2008). Different perspectives on accessibility across almost a century of research suggest that it can largely contribute to better planning transport and land-use systems,

and to increase and improve the ability of populations to reach opportunities that are relevant for economic, social and cultural development (Ferreira and Papa, 2020; Levine, 2020).

Despite a long history of accessibility in research and practice, its application to understand the effects of transport on social equity, inclusion and wellbeing has only gained traction in the last 20 years. In the Global South, such traction has materialised in a rising number of research in urban developing contexts, where specific social, economic and functional conditions have led to rethinking conceptual approaches and methods to urban mobilities and accessibility (Benevenuto and Caulfield, 2019; Niehaus et al., 2016; Pojani and Stead, 2015; Tao et al., 2023; Uteng and Lucas, 2017; Vecchio, 2020). One of such areas for conceptual and methodological developments is the analysis of informalities in transport, housing and the economy, and their influence on mobility and accessibility. While some studies have partially addressed the issue of job informality, most research has focused on informal transport and housing (Boisjoly et al., 2020; Golub, 2003; Heinrichs et al., 2017). Specific examples of research exploring accessibility and informality in the Global South include the cases of Sao Paulo (Boisjoly et al., 2017), Rio de Janeiro (Barboza et al., 2021; Motte et al., 2016), Lima (Scholl et al., 2016), Montevideo (Hernandez, 2018; Hernandez et al., 2020), and Mexico City (Suárez et al., 2016).

Accessibility enables measuring transport's ability enable individuals and social groups to meet their needs beyond more traditional indicators of travel time, expenditure and efficiency. Accessibility holds social value as a concept and as a planning tool, enabling researchers and practitioners to identify and give meaning to areas of transport disadvantage and with limited or no access to relevant opportunities (Lionjanga and Venter, 2018). The distribution of accessibility across urban geographies and socioeconomic groups also unearths inequalities stemming from the spatial and functional configuration of land-use and transport.

When accessibility to goods and services and the ability to travel to activities (that is relevant for participation in society) is removed as a consequence of a built environment that imposes physical movement as a precondition for accessing most opportunities it offers, people experience social exclusion (Giuliano et al., 2015; Koonings and Kruijt, 2007). In this regard, productive and social inclusion can be approached from an accessibility perspective as they are intrinsically related to the urban, economic and social structure of the city, operating both within and outside the timeframes and scales of formal employment. These conditions are often reinforced by poverty in its multiple dimensions, and low-quality and unavailability of public transport services and adequate infrastructure. Informality provides for an interesting lens to examine access inequalities and exclusion more in detail as although it is closely correlated with poverty, not all informal workers are poor. Similarly, research on social exclusion suggests that although social exclusion and poverty are closely related conditions, neither all people that experience transport-related social exclusion live in poor neighbourhoods nor that all people experiencing poverty are excluded (Schwanen et al., 2015).

According to Levitas et al. (2007), social exclusion involves a "lack or denial of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society, whether in economic, social, cultural

or political arenas". Kenyon et al. (2002) define transport-related exclusion as the inability of people to participate in the productive and social life due to low accessibility levels to opportunities caused by a deficient transport supply and/or insufficient ability and willingness to pay. This is relevant because transport barriers can constrain the ability to travel to reach employment and other opportunities, particularly in contexts where the supply of jobs is very centralised, and population is segregated.

In this study, we step away from the transport-related social exclusion definition that looks at transport as a driver of lack of access to essential opportunities and limited participation in society. Rather, we approach exclusion as both a consequence of lack of access to formal employment and a condition that defines levels of social and transport disadvantage. Access to formal labour markets is closely related to the concepts of social and productive inclusion. A first approach to the determinants such forms inclusion developed by Bhagwati (1988) assumes a pragmatic approach considering an indirect route (impacting income through growth acceleration) understood as the creation of income, and a direct route (social policy) that implies provision of means for consumption and asset accumulation. These two routes, which can be summarized as being able to participate in a city's formal economy and gain access to the social safety net it provides, need to be complementary. Some authors in Latin America have suggested that if governments are to increase the well-being of the urban population, they should promote both market and social incorporation simultaneously (Martínez Franzoni and Sánchez-Ancochea, 2014).

From this perspective, we adopt Angulo's (2015) framework for social and productive inclusion that define them as the conditions of access to social safety nets and economic activities, which considers Bhagwati (1988) proposed direct and indirect routes for inclusion. Such framework builds both on research on multi-dimensional poverty and its local manifestation in Latin America, and impact evaluations of social development programmes in Colombia targeting poverty reduction and integration to the formal economy (Angulo, 2016; Angulo and Gómez, 2014). We link Angulo's (2015) and Guataquí's et al. (2010) definitions presented in Section 2.1 to propose scales of exclusion that build on conditions of job informality.

Figure 1 summarises the framework of social and productive exclusion adopted for the analysis of accessibility and informal employment in Bogotá. As shown, the definition of 'social exclusion' (workers with no healthcare), matches Guataqui's definition of 'weakly informal'. According to this definition, these workers also classify as productively excluded, as the absence of healthcare automatically classifies a worker as informal. In Colombia, specific population segments have access to social support in the form of conditional cash transfers, subsidised access to healthcare, education, and other essential support networks as a result of progressive policies adopted by previous national governments (Angulo, 2015). The most effective of such policies, and a frequently used proxy for determining access to social safety nets, is healthcare, as targeting mechanisms for social policy use the same identification system than the subsidised public system for healthcare (*ibid.*). Economic analysis of access to social policy beyond the scope of this paper suggest that people in the baseline levels of access to

healthcare within the subsidised system are also likely to have access to other social programs and the safety net for securing wellbeing they provide (*ibid.*). In what refers to higher income-populations, it is also expected that people with access to healthcare, not necessarily subsidised, will also have access to other forms of social wellbeing.

Within the scope of this paper, it is not possible to be socially excluded and productively included, as someone without healthcare coverage will inevitably be regarded as informal and thus, productively excluded. However, the opposite does not necessarily apply, as further determinants of informality beyond healthcare can also account for the formality status of a worker. In this sense, a worker with healthcare coverage but no written contract can be seen as socially included but productively excluded. In this framework, formal workers will also comply simultaneously with all the necessary conditions of social and productive inclusion, or 'double inclusion' in Figure 1. Linking Angulo's (2015) conceptual framework to Guataquí's et al. (2010) definitions, as demonstrated by Figure 1, a worker can be categorised as either 'socially excluded', 'productively excluded' or 'included'[1]. These categories of informality-driven inclusion/exclusion will enable a more disaggregated analysis of accessibility and unpacking the contributions of the land-use and transport configuration in Bogotá to different degrees of inclusion.

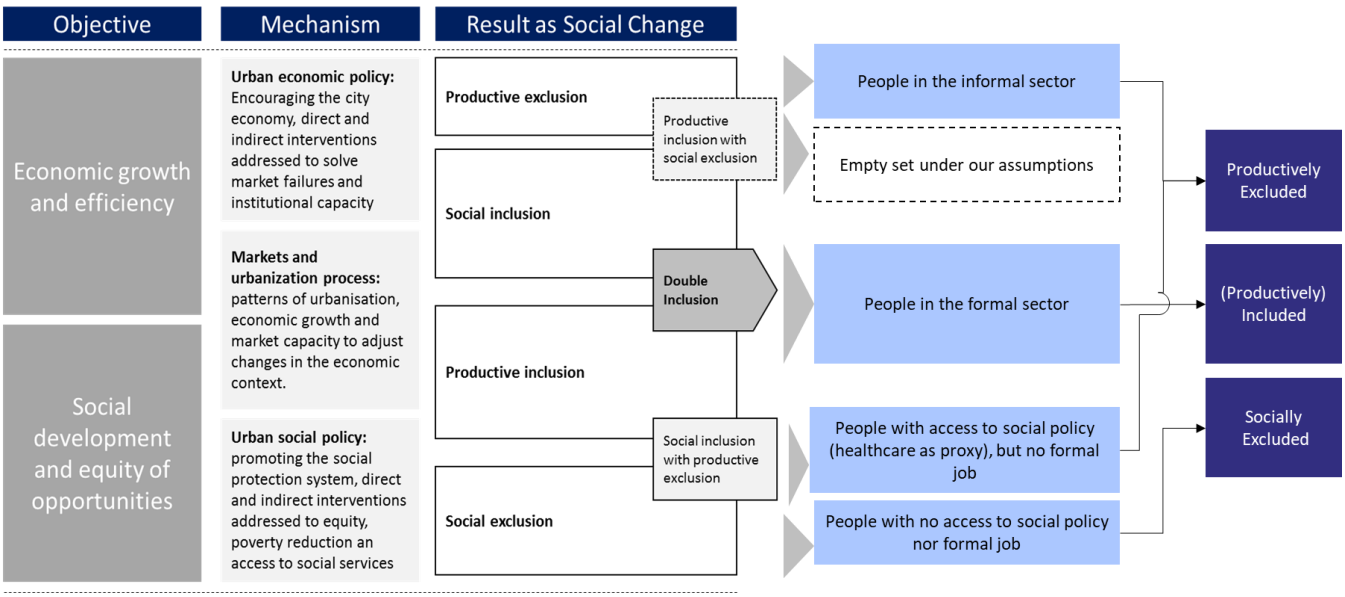


Figure 1 Definition of social and productive inclusion

Source: Authors, adapted from Angulo (2015)

[1] These definitions fulfill that:

(i) Social Exclusion rate = Weak Informality rate;

(ii) Social Exclusion rate + Productive Exclusion rate = Strong Informality rate;

(iii) Inclusion rate = Formality rate; and

(iv) Social Exclusion rate + Productive Exclusion rate + Inclusion rate = Strong Informality rate + Formality rate = 1

3. Bogotá: Segregation and informality

Bogotá, the capital city of Colombia, is a frequent reference in local and international research on transport, planning, and urban development (Castañeda, 2020; Combs, 2017; Montoya-Robledo and Escovar-Álvarez, 2020; Pucci et al., 2021; Vecchio, 2017). Research on the city suggests large-scale infrastructure and urban transport interventions such as the bus rapid transit (BRT) has played a significant role in the city's "mobility and accessibility, urban form and land markets, as well as both its positive and negative social and environmental consequences" (Oviedo and Guzman, 2020). The city has also been recognised in international transport policy and practice as a pioneer in sustainable urban policies, becoming a frequent reference for international development agencies and non-governmental organisations promoting sustainable development agendas (Montero, 2020, 2017).

Bogotá plays a key role in Colombia's economy, functioning as both its administrative capital and main economic centres for formal and informal employment. The city has an urban area around 400 km^2, with a population of 8.08 million people in 2017. Bogotá sits at the centre of a functional metropolitan area composed by 17 municipalities that have a close relationship with the capital city despite lacking an official metropolitan authority that governs their urban, social and economic interactions (Guzman et al., 2017a). Together, the 17 municipalities have a total population of 1.45 million inhabitants across 2,272 km^2, generating around three million trips daily. Most of these trips add to Bogotá's transport demand of over 15 million trips per day. Administratively, Bogotá is divided into 20 localities (19 urban and 1 rural), which allow to aggregate different quarters into spatially homogenous subdistricts, each with a local mayor and a local council. For the purpose of this paper, we will focus only in the 19 urban localities. Moreover, each locality groups constitute different zonal planning unit (*Unidad de Planeamiento Zonal*), hereafter UPZ, which are composed of adjacent neighborhoods. In total, Bogotá's 19 urban localities is composed of 114 UPZs.

Bogotá is also divided into socioeconomic strata (SES), which have been found in previous research to be a good proxy for income distribution (Cantillo-García et al., 2019). SES are distributed in a scale from 1 to 6, where 1 being a good proxy for poor households while 6 represents the wealthiest households in the city. Table 1 summarises some characteristics of the population by SES. As shown, average values for almost all socioeconomic features and put SES 1 and 2 at a relative disadvantage compared to middle (3 and 4) and high (5 and 6) SES. Lower purchasing power and capacity to travel, both in general and through the use of motorised forms of travel, provide further evidence supporting previous arguments about transport-related and access inequalities.

SES	1	2	3	4	5	6
Population (%]	9.6	42.1	35.3	8.6	2.8	1.6
Average income per HH* (USD)**	446.3	558.7	808.1	1,639.5	2,331.8	2,782.5
Household (HH) size	4.0	3.7	3.3	2.9	2.8	2.6
Workers by HH	0.44	0.45	0.46	0.51	0.49	0.57
Students by HH	0.30	0.29	0.25	0.22	0.24	0.20
Car-ownership per HH	0.11	0.20	0.45	1.03	1.39	1.59
Daily trips per member of HH	2.03	2.20	2.20	2.49	2.62	2.65

Motorised daily trips per member of HH	0.86	0.93	1.21	1.86	2.12	2.06
% of member of HH without motorised trips	17.0	16.3	17.4	15.4	14.2	16.0
Motorised travel time to work	79.3	66.3	57.4	50.9	48.5	39.7
Private transport (car and motorcycle) travel time to work	49.4	51.3	45.7	44.2	43.9	36.9
Public transport travel time to work	86.4	74.3	65.1	59.5	60.8	60.2

*HH income is per month

**USD from 2018

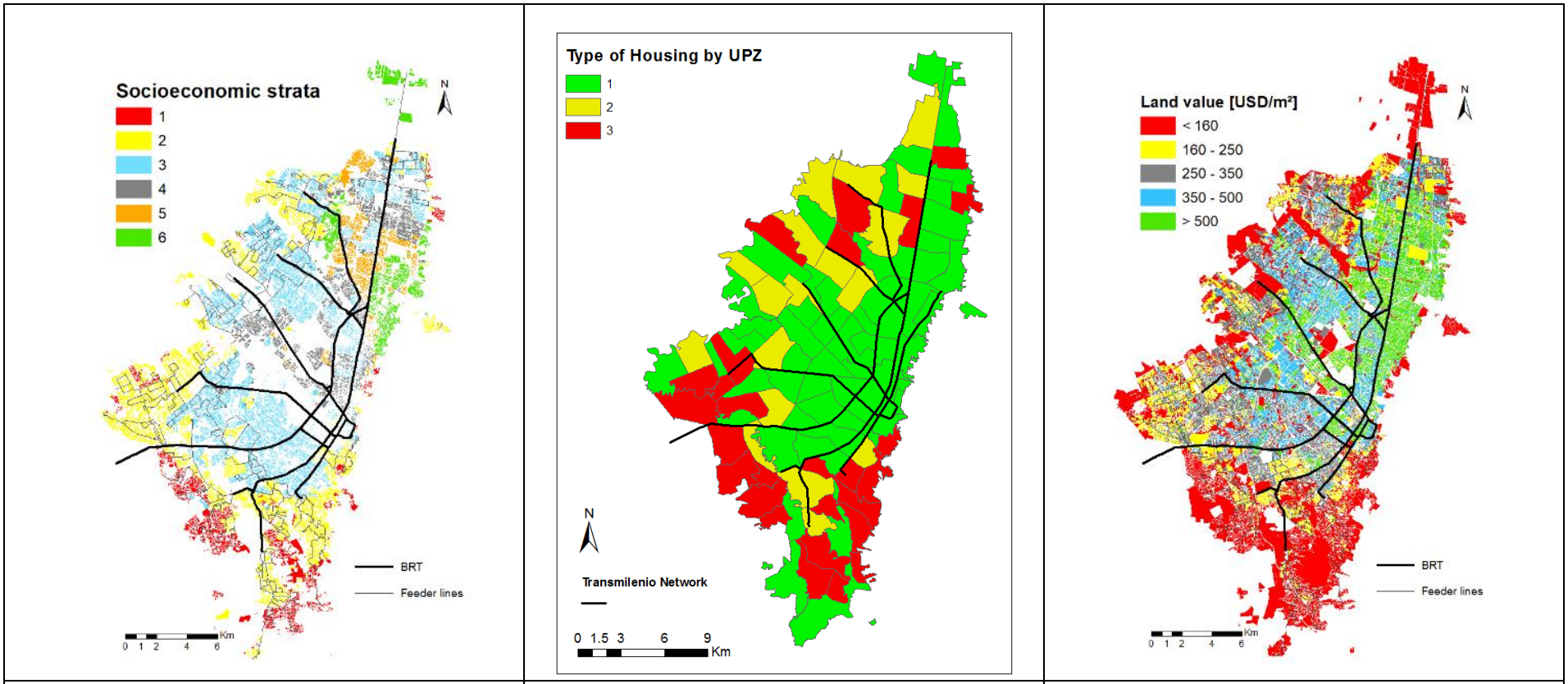
Table 1 Main household's characteristics by SES in Bogotá

Source: Authors, based on Household Travel Survey (HTS) 2015

The process of classifying housing by SES builds on a combination of social, economic and built environment characteristics (Figure 2, left). This unique model was devised in the mid-nineties to assign fares for public utilities in a country that had poverty rates close to 40% at the time. Today, the spirit of that model has contributed to encouraging spatial segregation in the city, leading to self-reinforcing cycles of urban development and increases in land prices that have created marked differentiations between higher and lower SES (Figure 2). Figure 2 (right) shows the categorisation of concentration of informal housing according to the origin of settlements in the locality, using a qualitative scale from 1 to 3 (1=formal; 2=mixed; 3=mainly informal) according to data from previous research on informal housing in the city (see Dávila et al., 2006). Over the years, low-income settlements of informal origin have been formalised by different local administrations, retrofitting basic utilities and infrastructure. However, lack of planning and control has negatively affected the urban quality of such neighbourhoods. Despite being formalised, many areas of informal origin concentrate high poverty levels and deficits in urban amenities, employment opportunities and public transport supply. By contrast, high levels of congestion and transport costs have attracted large part of the wealthy population back to the central/north city and other employment areas (in the east fringe), which encouraged speculation in these areas and promoted the construction of exclusive higher-density housing near the city centre (Figure 2).

The spatial distribution of informal housing has consequences for accessibility and is correlated with SES and land values, marking the divide between the 'formal' and the 'informal city' in terms of where the population lives. Such divide is also manifested in differences in connectivity between where the poor and the rest of the population live. Principles of economic rationality underpinning transport and infrastructure provision lead both to precarious coverage of roads, utilities and basic social services in 'less-profitable' areas of the city and increasing connectivity of wealthier neighbourhoods (Oviedo Hernandez and Dávila, 2016). These conditions feed upon a continuous cycle of spatial segregation and poverty that reshape city boundaries through informal settlements in the peripheries while developments near the city centre become increasingly expensive. Consequently, the forms of mobility of peripheral populations differ greatly from those living in more attractive and better-served areas of the

city, suggesting marked access inequalities between rich and poor (Guzman and Oviedo, 2018; Oviedo and Titheridge, 2016; Thibert and Osorio, 2014; Vecchio, 2020).



Strata	Informality	Land value*

* Cadastre values from 2016

Figure 2 Socioeconomic strata, housing type, and land value (residential use) in Bogotá

Source: Authors

The spatial and functional structure of Bogotá shown in Figure 2 is closely related to the distribution of employment across Bogotá, leading to disproportionately low access to workplaces in low-income neighbourhoods (Guzman et al., 2017b). The central business district (CBD) of Bogotá is the area of the city where the highest number of activities and employment agglomeration (Guzman et al., 2017a). As a company moves away from the CBD, the lower the land value and the lower the agglomeration benefits. The consequences of land and economic geography of Bogotá is that the largest employment concentration coincides with high land-rent areas. According to Angulo (2015), Bogotá ranks 6th in the inclusion ranking among the main 13 metropolitan areas in Colombia, suggesting spatial and economic dynamics may have an influence in the ability of different population groups to access employment. However, not all businesses can generate sufficient revenue to cover high rents and benefit from agglomeration in the CBD. Small and medium—often informal—enterprises focusing on low-skilled and often underpaid activities tend therefore to locate in the periphery. Figure 3 shows a heatmap of the main origins and destinations of work trips in Bogotá, which can serve as a reliable proxy for the concentration of job opportunities (Guzman et al., 2017b).

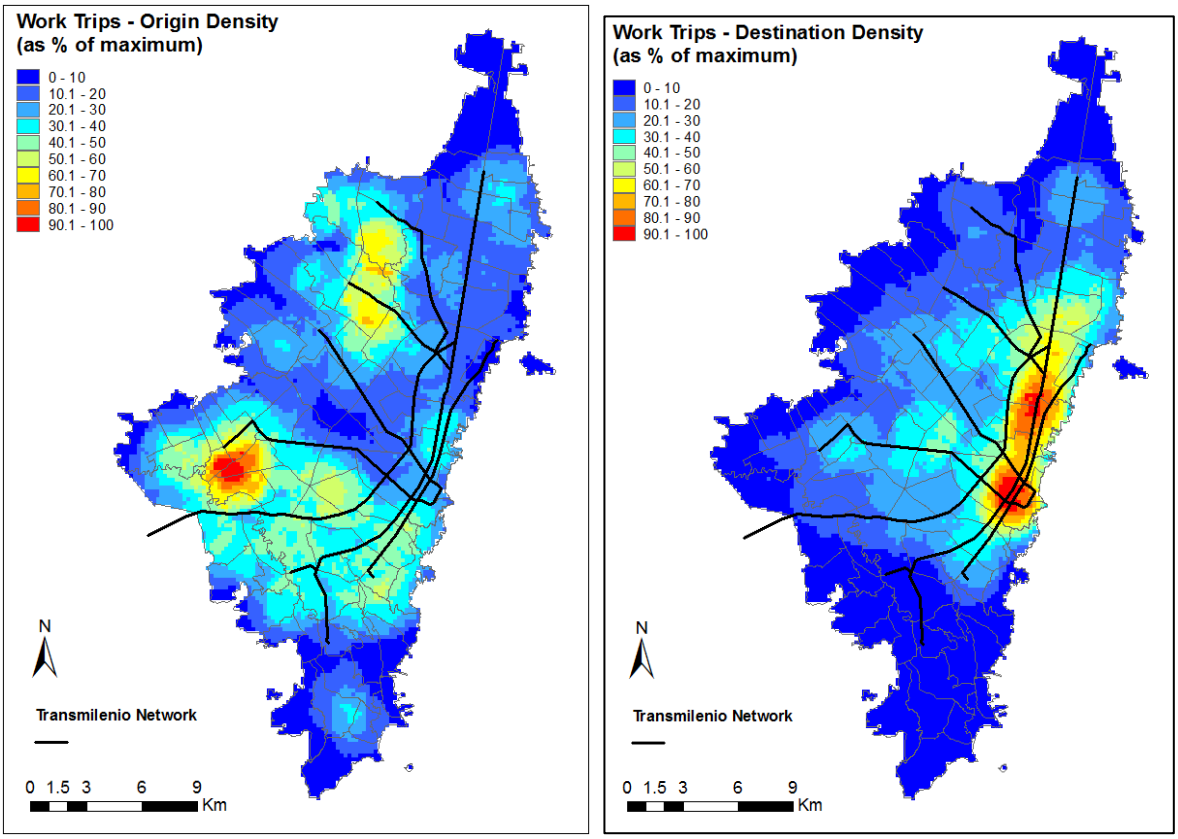


Figure 3 Density of origins and destinations of work trips in Bogotá

Source: Authors, based on HTS 2015

The distribution of origins and destinations of working trips in Figure 3 suggests employment opportunities, identified using the destinations as proxy, are in the formal city. By contrast, most labour force, using origins as a proxy, are in the low and middle SES neighbourhoods. These patterns replicate trends suggested in Figure 2 and are consistent with previous research (Guzman and Bocarejo, 2017). Patterns in Figure 3 suggest demand for work-related travel is

highly targeted towards well-defined and centralised locations and that most labour force lives far from the main areas of economic activities. Figures 2 and 3 also include the *TransMilenio* (BRT) network as indication of the areas served by high-capacity public transport infrastructure. The distribution of such infrastructure, suggest that connectivity has responded to unidirectional work-related travel patterns, reinforcing the connectivity in areas with high concentration of jobs. However, research exploring the historical development of such transport network indicate that it developed progressively, with nearly a decade between the first and third phase of BRT lane implementation which first served middle and high-income neighbourhoods and much later those neighbourhoods of lower SES (DANE, 2014).

4. Methodology

4.1.Spatialising exclusion

To assess the level of informality and exclusion at the city level, we relied on Bogotá's 2014 Multipurpose Survey (MPS), a city-level instrument to collect data about quality of life and purchasing power for monitoring and planning purposes (DANE, 2014). The MPS's sample includes 61,725 individual observations containing data on access to healthcare, pensions and formal labour, among other socioeconomic variables. For our analysis of informality and exclusion we narrowed down the data by considering the population classified as 'employed' under DANE's definition. Following the criteria in Figure 1, we categorised the formality and inclusion status of each worker. The resulting classification is summarised in Figure 4.

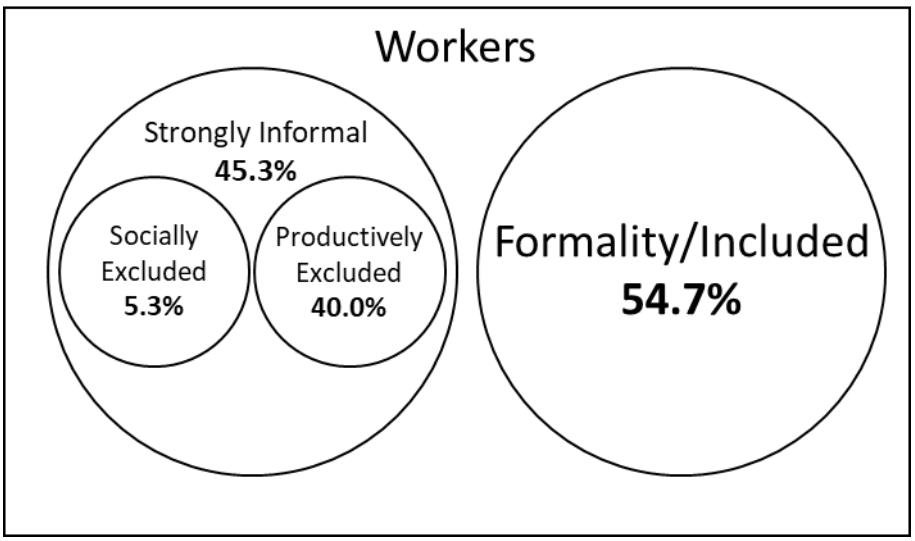


Figure 4 Social and productive inclusion and informality in Bogotá

Source: Authors, based on MPS 2014

Figure 4 summarises the distribution of the working population in the MPS by categories of social inclusion, productive inclusion, and job informality in Bogotá. As of 2014, 5.31% of the total workers in Bogotá were working without any form of healthcare coverage, assuming the costs of work-related risks and illnesses. Moreover, 40% of the total working population had access to healthcare without a written contract, a pension scheme, or both, which according to

the framework in Figure 1 is classified as socially included but productively excluded. The sum of the former categories accounted for a strong informality rate of 45.3%, leaving almost 54.7% of the remaining working population both socially and productively included (formal workers).

The research builds on the HTS 2015 and MPS 2014 to classify and locate informal workers' spatial distribution and patterns of work-related trips. Using data in the MPS, we divided Bogotá in a combination of 19 localities and 6 SES, considering different households within the same neighbourhood tend to have the same SES. From an initial possible 114 locality-SES in which a worker could live, the total number of zones for analysis is reduced to 86 homogeneously distributed areas where a worker could live since not all localities include all SES.

Using the criteria in our analytical framework, we estimated the distribution of social exclusion, productive exclusion, and inclusion rates in each of the 86 locality-SES, allowing us to map labour informality of households in Bogotá. Using this calculation enables us to categorise each area by exclusion/inclusion rates, comparing them with city-level rates as a benchmark for levels of exclusion. Using different thresholds for levels of exclusion/inclusion in each category, we defined a set of three dichotomic variables that take the value of 1 if the locality-SES shows a higher value than the benchmark.

Bogotá's 2015 HTS allows us to identify geocoded information about origins and destinations for work trips. Using the geocoded data from the HTS and the 86 locality-SES zones defined from the MPS we spatially matched origins and destinations, allowing us to analyse travel patterns by aggregated categories of exclusion/inclusion. The analysis assumes that if a working trip's origin falls within a specific locality-SES, the worker will likely have similar exclusion/inclusion attributes to the zones. This gives us a proxy for estimating the commuting destinations of workers living in areas with specific levels of informality and exclusion. This method is an attempt to overcome the constraints imposed by lack of labour-specific metrics in the HTS that prevent estimations at the observation level.

4.2.Measuring accessibility

Accessibility links availability of individual resources and assets for travel with structural conditions such as the distribution of opportunities in space and the availability of transport infrastructure and services. A straightforward way to think about accessibility is as the level of easiness or difficultness that individuals experience when reaching opportunities they value, such as employment, health, education, or leisure. This easiness or difficultness considers elements of the transport infrastructure like travel times, fare, and frequency of service, as well as the spatial distribution of the opportunities and the economic and social characteristics of travellers. It is also a concept that is relative and dynamic, as it can be measured in relation to other individuals or groups, changes over time, and can be defined at different scales, from individual to neighbourhoods and communities (Jones and Lucas, 2012; Lucas, 2019). Many approaches to measure accessibility have been proposed in literature. Geurs and van Wee (2004) group the different accessibility measures into infrastructure-based measures, location-based measures, person-based measures, and utility-based measures.

Probably the most popular mechanism to quantify accessibility applied by scholar and practitioners is by using the potential accessibility model. In this article we apply a traditional potential accessibility model that has also been used extensively in the context of Bogotá (Bocarejo and Oviedo, 2012; Guzman et al., 2018; Guzman et al., 2017b; Oviedo and Guzman, 2020). The potential accessibility model is inspired in the planetary gravitational law and enables to model observed flows of trips in urban areas. Its main logic is that zones with a higher number of opportunities are expected to attract a higher number of trips and that trips between non-distant zones are easier to happen than tripes between distant trips. Moreover, the notion of distance is extended to other variables like travel time and cost. A usual name for the extended notion of distance is generalized cost of travel, impedance function, or friction. The potential accessibility model operates as a linear regression model and is linked to spatial interaction models (SIM) (Östh et al., 2014). As shown below, the potential accessibility model enables to calculate how many 'potentials' formal and informal employment opportunities dwellers can reach given their place of residence and economic characteristics and based on this calculation, we move to other analysis.

Equation 1 assesses the level of accessibility of an origin (locality-SES), considering the total number of potential opportunities that an individual can reach given time and economic costs necessary to access such opportunities.

$$A_i = \sum_j^J \bar{a}_{i,j} \text{ (Equation 1)}$$

Here, A_i is the total accessibility of locality-SES i, which is the sum of the average accessibility $\bar{a}_{i,j}$ than an individual commuter travelling from locality-SES i to any destination UPZ j, considering a total of 114 UPZs. We use UPZs instead of localities as the unit of analysis of destinations as they constitute a more disaggregated unit of analysis. Analysing the destination using UPZs can provide more information about trips within specific locality-SES, as well as cover the whole of Bogotá's urban area.

Average accessibility $\bar{a}_{i,j}$ is estimated over the individual accessibility that commuter k travelling from i to j has and considering all $n_{i,j}$ commuters within the survey with the same travel pattern (see Equation 2).

$$\bar{a}_{i,j} = \frac{\sum_k^{n_{i,j}} a_{k,i,j}}{n_{i,j}} \text{ (Equation 2)}$$

Individual accessibility $a_{k,i,j}$ is calculated as the potential job opportunities (work trip destinations) available at the destination of commuter k (i.e. UPZ j) times an impedance coefficient in function of the distance $d_{k,i,j}$ between i and k (see Equation 3).

$$a_{k,i,j} = o_j * f\left(d_{k,i,j}\right) \text{ (Equation 3)}$$

Equations 4 and 5 show the calculations for impedance coefficients, which use as an input the total travel costs $C_{k,i,j}$ reported by worker k. These include both monetary costs $Cm_{k,i,j}$ (i.e.

bus tickets, taxi fares paid, etc.) and time costs $Ct_{k,i,j}$ (length in minutes of the commute), converted at a cost-per-minute rate h_i defined for a worker living in the origin i.

$$f(d_{k,i,j}) = e^{-\beta_i C_{k,i,j}} \text{ (Equation 4)}$$

$$C_{k,i,j} = Ct_{k,i,j} * h_i + Cm_{k,i,j} \text{ (Equation 5)}$$

The beta parameters by SES of the formula were calibrated based on the 2011 HTS, which includes a much larger sample compared to the 2015 HTS. We use parameters estimated for each SES and differentiated by public and private transport in an early study (see Guzman et al., 2017b for elaboration).

	Strata 1	**Strata 2**	**Strata 3**	**Strata 4**	**Strata 5**	**Strata 6**
Impedance (b)	-0.0286*** (0.000647)	-0.0405*** (0.000550)	-0.0517*** (0.000939)	-0.0548*** (0.00168)	-0.0545*** (0.00290)	-0.0550*** (0.00305)
Observations	459	2,012	1,662	762	186	179
R-Squared	0.810	0.730	0.646	0.582	0.656	0.646

Standard errors in parentheses
*** p<0.01, **p<0.05, *p<0.1

Table 2 Accessibility impedance parameters by SES

Source: Guzman et al., 2017b

5. Findings

5.1.Mapping labour informality

Using the criteria for informality defined by Guataquí et al. (2010) and the classification presented in section 4.1, we estimated the concentration of informal labour by locality-SES. Figure 5 shows the spatial distribution of labour informality at the household location in Bogotá using the 86 zones described in section 4. While this zoning is aggregated in comparison with the level of spatial detail of data in the HTS, it still allows for analysis of spatial trends and correlations with other variables such as those presented in Figure 2. The informality rate in Figure 5 reflects the percentage of informal workers, understood as all workers in the locality-SES that do not meet all criteria: i) having and paying for his/her own healthcare, ii) being registered in the pensions system and contributing to a pension scheme and, iii) working under a written contract. We find that there is a high spatial correlation between poverty (as measured by SES), lower land values, housing informality and job informality. These conditions represent intersecting social disadvantages, which are reinforced by lower coverage of public transport, adequate transport infrastructure, and other transport disadvantages in line with both local and international literature (Benevenuto and Caulfield, 2019; Guzman et al., 2018; Lucas, 2019; Oviedo and Titheridge, 2016). Figure 5 suggests that the informal worker lives in the 'informal city' adding a layer of complexity to structural processes of segregation and exclusion resulting from the way transport and urban development has taken place in Bogotá over the years (Oviedo Hernandez and Dávila, 2016).

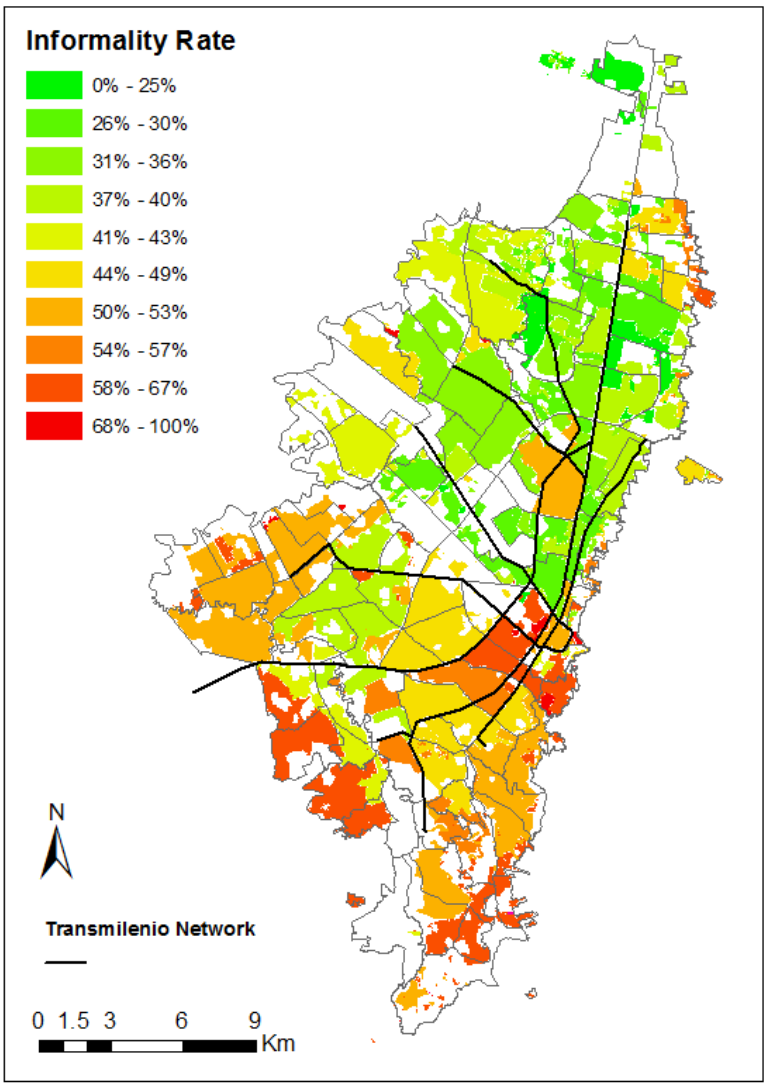
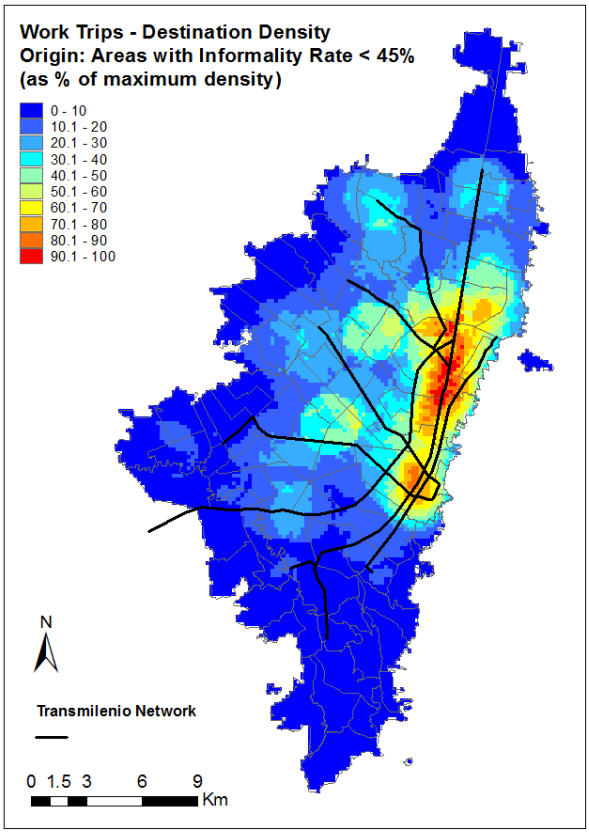


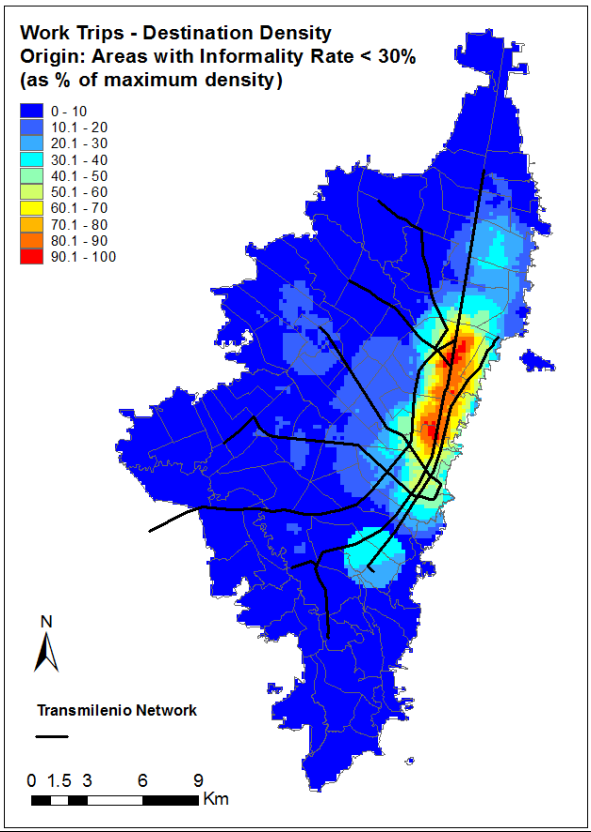
Figure 5 Employment informality rate at the household by locality-SES

Source: Authors, based on MPS 2014

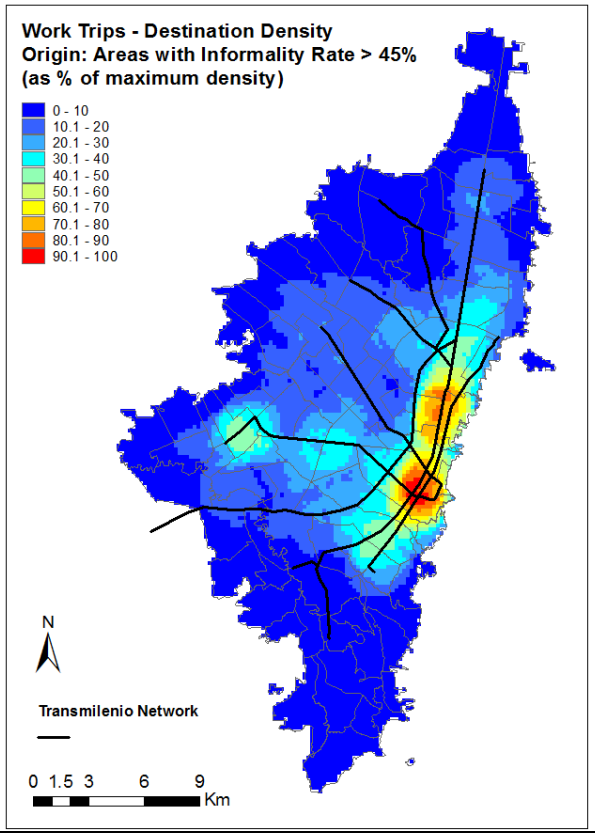
Building on findings summarised in Figure 5 and the HTS, we mapped the destinations of formal and informal workers for different thresholds of concentration of informal workers in each locality-SES. We use different thresholds to reflect the variability in the transport geographies of zones with different levels if informality, recognising that the concentration of informal workers by locality-SES does not necessarily reflect the specific formality status of each commuter. Analysis summarised in Figure 6 therefore seek to estimate how work locations vary for neighbourhoods with larger concentrations of informal workers, testing whether clusters of informal destinations are similar to those of formal workers. We use thresholds of informality rates above and below the city level average (Figure 6 (a) and (c)) and thresholds for low and high informality using the lower and higher tails of the distribution of informality by locality-SES (Figure 6 (b) and (d)).



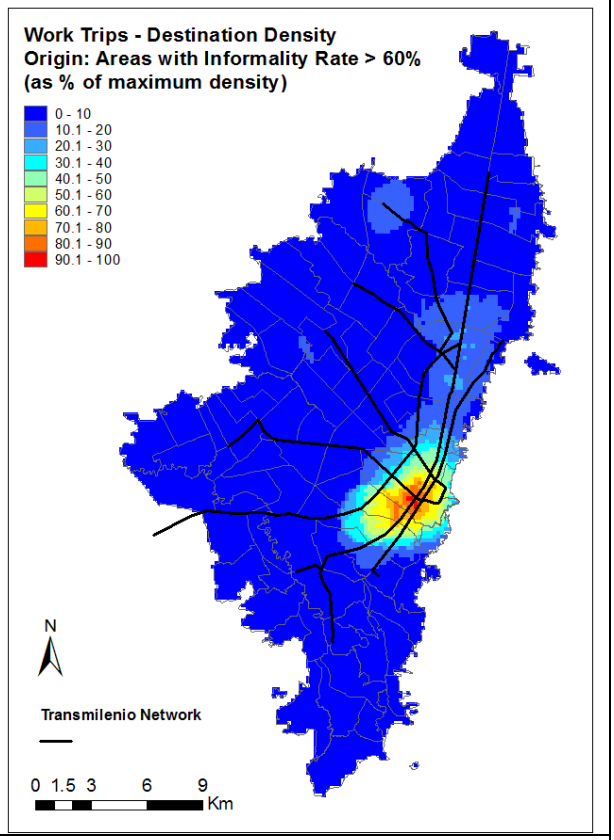
(a) Informality rate < 45% (below city average)



(b) Informality rate < 30% (Mostly formal)



(c) informality rate > 45% (above city average)



(d) informality rate > 60% (Mostly informal)

Figure 6 Work-trip destinations by concentration of informality

Source: Authors, based on MPS 2014 and HTS 2015

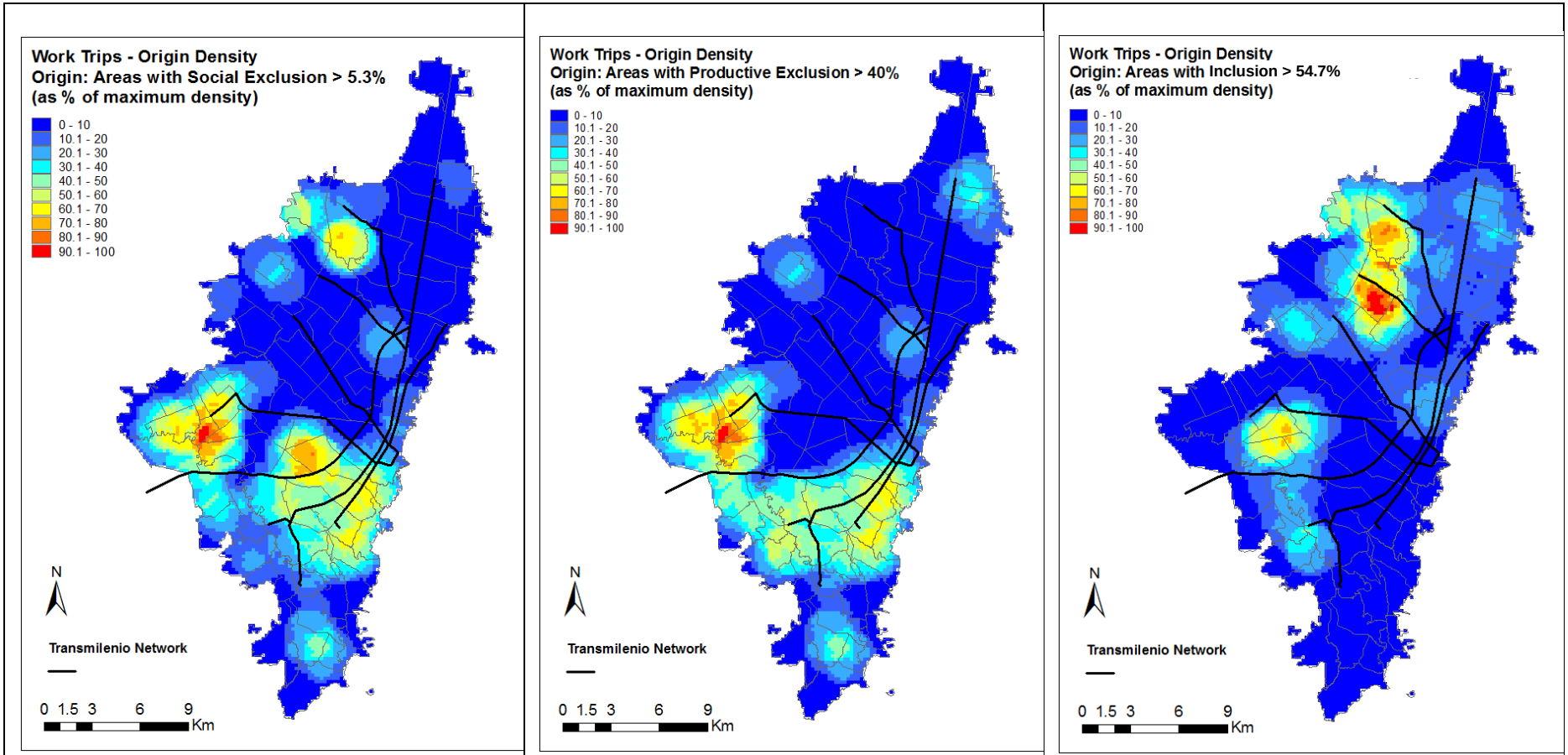
Results in Figure 6 show that as concentration of informal workers increase, clusters of destinations for informal jobs narrows down very quickly to hotspots. In the case of formal jobs, clusters of high demand coincide with the aggregated destinations in the extended CBD shown for the whole sample in the HTS. The opposite is true for high concentrations of informal workers, suggesting that commuters in areas where a majority of the residents work in the informal economy travel more frequently to a single, well-defined hotspot, near the older part of the CBD. Considering Bogotá's segregated urban structured highlighted in Section 3, results in Figure 5 and 6 (d) suggest that citizens in the zones with higher concentration of informality have higher travel distances and lower connectivity via high-capacity public transport. This has implications for transport supply and demand, as well as for the economic geography of Bogotá, contributing to understanding what the contribution of public transport and connectivity to informal job supply is. The fact that the main cluster of informal jobs is spatially closer to the 'informal city', as well as to the southern end of the city where poorer and less-connected neighbourhoods concentrate, can serve as indication of a systematic bypassing of socially vulnerable populations in the process of transport planning and delivery.

5.2. Exclusion

Building on findings about origins and destinations of informal workers, we spatialise exclusion using the categorisation proposed in Figure 1. While the dynamic process of social exclusion does not necessarily entail complete deprivation from access to socioeconomic opportunities, resources, interactions, and information, it can involve considerable risks of "rupturing of the 'social bond' at the individual and collective levels", with the accumulation of dimensions of exclusion that leads to deeper levels of socioeconomic vulnerability and deprivation (Samuel et al., 2018; Silver, 2007, p. 1). Our narrower definition of exclusion seeks to reflect levels of disadvantage and social vulnerability of citizens, rather than a measure of the consequences of lower accessibility. This analysis examines the intersections between transport disadvantages with social disadvantages associated with precarious livelihoods and limited participation in the formal economy (Lucas and Porter, 2016). This approach is compatible with definitions in transport and social development studies (Lucas, 2019). We analyse the three categories separately, using the average values at the city level as benchmarks. We therefore analyse working destinations of residents of locality-SES with exclusion/inclusion rates above the city's average.

The results of the analysis of the spatial distribution of the three categories of job-related exclusion are presented in Figure 7. Findings on the categories of exclusion show that social and productive exclusion, (i.e., work-trip origins of workers living in areas with exclusion/inclusion rates higher than the city's average), tend to be concentrated in areas of higher social and transport disadvantage in the case of the two types of exclusion (Figure 7 (a) and (b)) and in areas with higher concentration of mid-SES population in the case of inclusion

(Figure 7 (c)). An exception is the social exclusion hotspot located in the north-western end of the city, which not found in the map of productive exclusion.



(a) Social exclusion (above city's average)

(b) Productive exclusion (above city's average)

(c) Inclusion (above city's average)

Figure 7 Location of areas with productive and social exclusion

Source: Authors, based on MPS 2014 and HTS 2015

5.3.Accessibility

We finally attempt to analyse and spatialise transport accessibility to jobs by public transport and by group of exclusion. To do so, and as we did before, we analysed only those workers living in areas with higher exclusion/inclusion rates than the City's average. Results show that roughly 67% of Bogotá's workers (approximately two million out of city's total 2.9 million) live in areas with social exclusion rates higher than the city's average of 5.3%. However, these workers can only access to 58% of the city's labour opportunities. Similar results are present when analysing productive exclusion—whereas almost 60% of the population live in areas with higher-than-the-average rates of productive inclusion, they have access to less than 55% of the city's labour opportunities. In the case of the inclusion, results are the opposite, as 41.4% of the workers live in areas with higher inclusion rate than the city's average but they have access to a greater percentage (43.8%) of the working opportunities the city offers.

These results are clearer when analysing the number of accessed jobs per capita in each category—as the probability of being included improves, workers can potentially access more jobs per capita. This suggests there is a high level of inequality in labour accessibly across the population. To assess this, we used the Gini coefficient, the most common measurement of inequality, to calculate the inequality of distribution for labour accessibility (Table 3). The Gini coefficient measures on a scale from 0 to 1, where the value 0 indicates perfect equality and the values 1 indicates perfect inequality; sometimes it is presented as a percentage from 0 to 100% (Hasell, 2023). The higher values of the Gini coefficient thus indicate higher inequality (*ibid.*). The variable typically measured in the calculation of the Gini coefficient is 'wage', or more generally, 'income' (Luebker, 2010), which was, within the scope of this study, replaced by the variable 'potentially accesses jobs'. The value of 0.4 is a warning level/tipping point set by the United Nations—when the income disparity of a country exceeds the value of 0.4, it may confront higher risks of political and social instability, elite capture, as well as greater constraints to poverty reduction (Haddad et al., 2024; UN System Chief Executives Board for Coordination, 2017). We followed the 0.4 warning level/tipping point, and the result is a Gini coefficient of 0.40 for the entire sample available, which falls within the level set by the United Nations. This result suggests there is a high level of inequality when accessing jobs across the sample.

We finally proceed to spatialise these results by mapping accessibility at the level of locality-SES. Intuitively, our results show that such areas that tend to have a higher level of aggregated accessibility are those closer to *TransMilenio* (BRT) trunks. However, when analysing the spatial distribution of per capita accessibility, the initial layout of accessibility changes towards one in which the poorest and furthest away areas in which the informal and the excluded are concentrated, far away from the employment location, present significantly lower levels of potential accessibility to jobs per inhabitant.

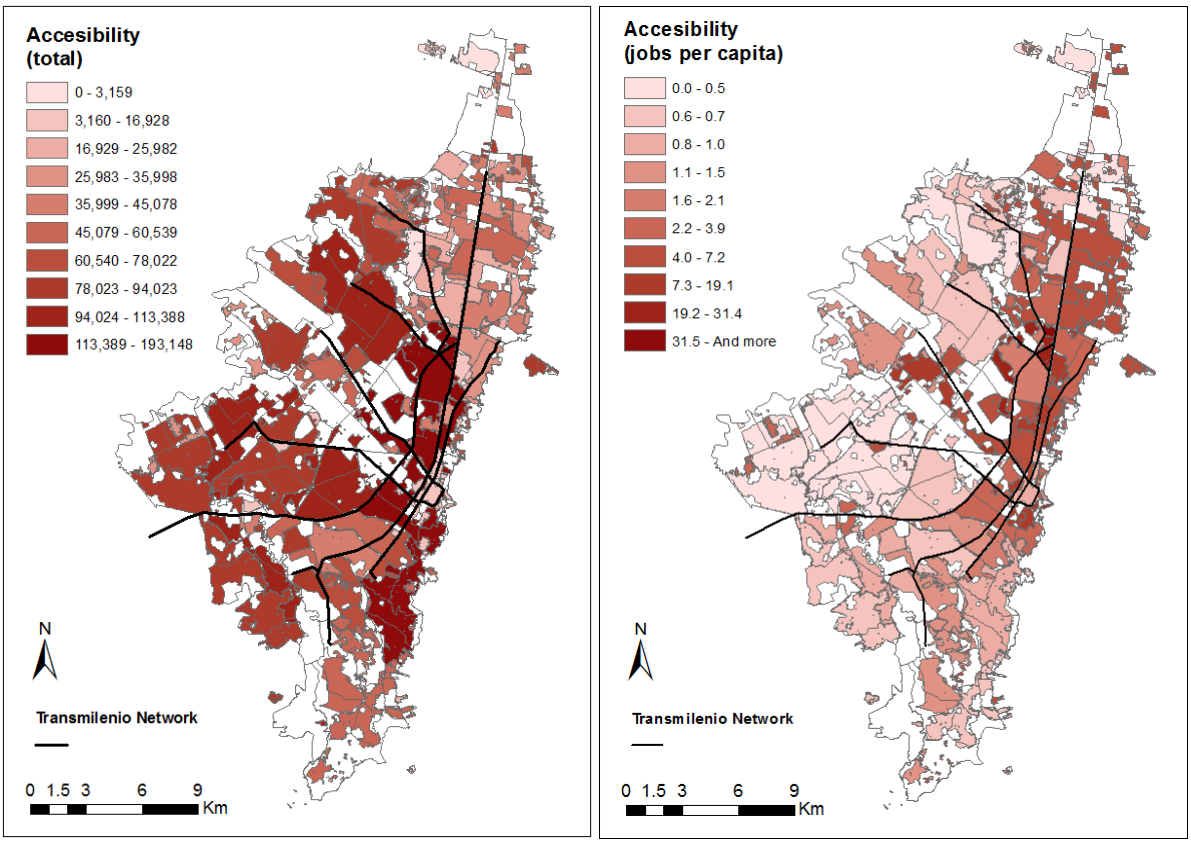


Figure 8 Accessibility levels

Source: Authors

When comparing this finding with the results of productive exclusion, we can see a strong, positive spatial correlation between the two socioeconomic phenomena. This means that, while aggregate accessibility is correlated with provision of transport infrastructure, per capita accessibility has a stronger connection with proximity to jobs. Three main findings can be drawn from this. First, that the lowest per capita accessibility can be found in excluded areas. Second, that public transport does connect excluded areas with hotspots of both formal and informal employment, although this has been done only in the latest developments and expansions of the system. Third, that there exists a higher dependency of feeding systems in excluded areas.

We finally proceed to estimate the cumulative distribution of transport accessibility (Lorentz curves) and the resulting Gini coefficient for each of the exclusion groups and for the overall population. Our intention with this is to estimate how unequal the distribution of accessibility is in function of the exclusion status of a group. Results show that those regarded as socially excluded tend to be more homogeneous in terms of accessibility whilst the productively excluded, which may have enough income to afford healthcare but still labour in the informal economy, have a more unequal distribution of transport accessibility represented by a higher Gini coefficient in such group. The results are summarised in Table 3 below.

	Threshold	Number of accessed jobs		Population		Jobs per capita	Gini
Social exclusion	5.3%	2,152,651	*58.0%*	1,996,721	*67.0%*	1.08	0.37
Productive exclusion	40.0%	2,022,049	*54.5%*	1,750,884	*58.7%*	1.15	0.40
Inclusion	54.7%	1,627,113	*43.8%*	1,235,617	*41.4%*	1.32	0.38
Overall		3,713,042	*100.0%*	2,982,061	*100.0%*	1.25	0.40

Table 3 Accessibility by segment

Source: Authors

6. Discussion and conclusion

Bogotá, much like other large cities in LAC, is characterised by a concentration of economic activity in its CBD and a peripheralisation of low-income workers (i.e., segregated distribution of housing by income level) underserved by an unequal provision of public transport. This results in a spatial mismatch between housing and employment that is further exacerbated by the informal economy, creating and reinforcing dynamics of social and productive exclusion in the city. Previous research by Cui et al. (2019) and Giannotti et al. (2021) have demonstrated the negative impacts of transport inequalities among different income groups on social equity, labour competition, and accessibility to jobs, particularly low-income ones in Brazil (São Paulo), Canada (Toronto, Montreal, and Vancouver), and the United Kingdom (London). Our study contributes to this body of literature through the conceptual inclusion of informality in the analysis. Specifically, we examined the relationship between informal employment, transport accessibility, as well as social and productive inclusion, considering Bogotá as a representative case study of rapidly growing cities in the Global South, in which there is widespread informality. Through focusing on the mobility needs of low-skilled and low-income workers in the informal economy, our study contributes and informs current debates on the link between public transport accessibility and employment by broadening the scope of social consideration in transport planning for targeted policies that prioritise the goals of inclusion and equity.

Bogotá has been successful through the direct route (social policy inclusion) to provide a safety net for people in the labour force. However, spatial distribution of socially excluded makes it difficult to expand the social safety net further to protect the most vulnerable and disadvantaged workers. Nearly half of Bogotá's population still has no access to non-precarious employment conditions (productive exclusion). Transport connectivity has the potential to increase access to formal activities for socially excluded, allowing access to healthcare and other social safety nets. The incremental development of mass public transit in Bogotá catered first for the formal demand and supply of employment, obeying to the conventional paradigms of transport planning. Furthermore, the current transport infrastructure and service coverage, notably higher capacity modes, continues to prioritise high-income areas.

Recent empirical studies have demonstrated that informal jobs may be more spatially dispersed and temporally irregular, creating new trends and challenges in reducing social and productive exclusion (Montoya-Robledo and Escovar-Álvarez, 2020; Oviedo and Guzmán, 2020; Pucci et al., 2021). For people experiencing conditions of exclusion, access to goods and services and

the ability to travel to activities relevant for normal participation in society is removed as a result of an urban environment that imposes physical movement as a precondition for accessing most opportunities it offers. These conditions are often reinforced by poverty in its multiple dimensions, and a low quality of public transport services in neighbourhoods with low car ownership and high dependency from informal employment. Although the concepts of economic and social exclusion find its origins in work that sought to improve our understanding and representation of poverty, it has since evolved to describe barriers that can prevent full participation in society. These barriers, similar to conditions of poverty, can include conditions such as low income and unemployment, but also precarious conditions for accessibility and quality of opportunities.

In addition, accessibility analysis for different categories of exclusion allows to identify gaps in transport-related benefits and target interventions for redistribution, accounting for some of the benefits of using this approach to analyse the impacts of transport provision. High inequality between productively excluded and socially excluded is evident, although there are similar levels of exclusion in worse-off groups. Widespread informality therefore not only impacts accessibility to employment, but also reinforces the structural conditions of spatial mismatch of economic activity concentrating within the CBD and low-income households and individuals in the peripheries.

The methodology used in this study can be replicated in contexts where information on employment, housing, travel costs and trip patterns are sufficiently available. The incorporation of Gini coefficient (a statistical measure of inequality) in the analysis of accessibility strengthens the identification and visualisation of differences in access to employment, highlighting the social consequences of transport and land-use policies. While the MPS data used in this study was published in 2014, and in some regard, it is increasingly out of date to examine more recent affairs such as the unequal impacts of the COVID-19 pandemic on Bogotá's population and their health and mobility and the usage patterns of ride-hailing services, the MPS adopted statistical techniques to capture hard-to-measure population groups to ensure robust statistical representation. As a result, the MPS data produced dwarf other surveys done in terms of scope, allowing measurements of social, economic, and demographic variation across neighbourhoods to be identified, monitored, and evaluated for the creation of relevant district policies. A new MPS will be conducted in early 2025 with the first available results expected to be published at the end of 2025 (UN World Data Forum, 2024).

Further research in examine accessibility to informal sector is necessary to determine areas in which policy interventions and new transport investments should be prioritised to enhance the productive inclusion of vulnerable and disadvantaged population. Additional data are also required in the integration of social and planning policies across different urban sectors to improve accessibility to secure and stable employment and to achieve full coverage of healthcare and social security in Bogotá and other cities across LAC.

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