Thesis for the degree of Master of Sc. in Economics

Better or Worse Job Accessibility? Understanding Changes in Spatial Mismatch at the Intra-urban Level in Medellín

Victor David Bernal Pavas*

Advisors:
Gustavo Adolfo García Cruz †
Jorge Eduardo Pérez Pérez‡

Abstract

We analyze accessibility to jobs through different transportation modes and the extent of job spatial mismatch at the intra-urban level. We use data from Medellin from 2012 to 2017 and measure accessibility through a Hansen equation approach. We find that despite of the continuous investment in public transportation and transport infrastructure, spatial mismatch has increased, and it is considerably larger for job seekers and workers using public transport compared to those using private transport.

Keywords: Spatial Mismatch, public transport, travel times, accessibility at intra-urban level, labor outcome

JEL Classification: J10, J70, R10, R12, R42

*MSc. in Economics student, Universidad EAFIT, Medellín, Colombia. E-mail: vdbernalp@eafit.edu.co

†Associate professor in the School of Economics and Finance at Universidad Eafit, Medellín, Colombia. E-mail: ggarci24@eafit.edu.co

‡Researcher at Banco de Mexico, Mexico DF, Mexico. E-mail: jorgepp@banxico.org.mx

1 Introduction

Spatial disconnection from jobs may lead to negative labor market outcomes, such as reduced labor earnings, a low employment rate or low-quality jobs. The negative relationship between spatial disconnection from jobs and positive labor market outcomes is referred to as the Spatial Mismatch Hypothesis (SMH) (Gobillon, Selod, & Zenou, 2007). Better job accessibility not only reduces travel times, but also improves local labor market conditions, thus, getting a closer job to home can be seen as an increase in social welfare (Ong & Blumenberg, 1998). Therefore, job quality and its accessibility are in the spotlight for any society, and studying how these variables are interrelated can help mitigate spatial segregation.

Heilmann (2014) shows that from an urban economics perspective, social gaps are not only a poverty problem but also a spatial problem. Job opportunities for welfare recipients are highly dependent on people's location, and this dependence can be compensated by improving transport accessibility. Differential job opportunities lead to income inequality and low quality jobs. In developing countries this problem is specially challenging, inequality and unemployment are accentuated.

In Medellín, Colombia, public transport and infrastructure policies have been very relevant during the last few years, and urban segregation has been a focus of debate. Therefore, it is interesting and policy-relevant to analyze how spatial disconnection from jobs has evolved in Medellín, and how this spatial disconnection has affected the city's labor market. Travel times have been increasing year after year for all kinds of trips in the city. In 2012, an average trip in Medellín used to take 33 minutes while in 2017 that time increased to 36 minutes. (Medellín Cómo Vamos, 2017).

This paper aims to find evidence of the spatial mismatch's evolution in Medellín, and what has been the impact of public policies to decrease its negative effects. We do it by defining a measure of the spatial distribution of employment at every possible destination weighted trough travel times, we measure for three different modes of transportation: private transport, public transport and walking. This accessibility measure is an inverse measure of spatial mismatch, since low accessibility implies larger disconnection from jobs.

We find evidence of decreasing accessibility despite of an increasing number of jobs and investment in new transport infrastructure. We also find that Workers who are able to commute by private transport have larger job accessibility.

This paper contributes initially offering an alternative way to capture employment at destiny from an origin-destination survey when there is not more available data. The main contribution is setting up and employ a very simple but very powerful measure to analyze spatial mismatch, which enable to track it trough time and compare it among different modes of transport. It also helps to show evidence of spatial mismatch at the intra-urban level in the context of a developing country. The most of evidence on this issue is to developed countries and there are few studies that carry out analysis within city.

The remainder of this paper is organized as follows: Section 2 presents background and reviews the literature. Section 3 describes the procedures we employed to capture employment and mismatch. Section 4 describes data and the challenges we faced with the available data. It also presents some description of the travel times by different means and the spatial distribution of employment across the city. Section 5 analyze the accessibility measure computed for 2012 and 2017, the evolution between both years and some explanations that provide evidence of the mismatch's evolution. Last, section 6 summarizes our findings.

2 Related literature

The Spatial Mismatch Hypothesis (SMH) initially studied the relationship between housing market segregation and non-white employment (Kain, 1968). Since then, the concept has evolved, and it has been in the spotlight of academic research in labor markets and urban economics since 1990. Spatial mismatch can be defined as a geographical disconnection between jobs and job seekers. According to Gobillon et al. (2007), SMH may be associated with negative labor market outcomes and welfare losses. Some of the mechanisms that may produce SMH and its negative consequences are high commuting costs, inefficient job search, territorial discrimination and low productivity.

Spatial mismatch appears in any kind of territorial unit. Even though most of papers focus on cities, there is also supporting evidence of spatial mismatch between countries. Taylor and Bradley (1997) found evidence of spatial disparities across Europe which led to high unemployment rates and differential wages. It is also a challenge even in developed cities. Stacy, Meixell, and Lei (2019) found strong evidence of mismatch in San Francisco and Columbus, cities with tight labor markets and abundant job offers. According to this research, there are three main approaches to tackle the problem: strengthening career pathways, creating housing near jobs and transit, and improving access to public transit.

In developing countries the effects of spatial mismatch may be stronger. Akbar and Duranton (2017) analyzed the cost of congestion in Bogotá estimating the deadweight loss of congestion using the demand and supply of travel. They found evidence of a small deadweight loss of congestion which was about 1% of the wage, but congestion costs can not only be related with time cost, it also has a cost in terms of labor outcomes that are measured in a spatial mismatch analysis

SMH has a close relationship with the job-education mismatch. For a worker, the likelihood of having a job that requires less education than the level they have, or outside their field of study, increases when there is spatial disconnection from jobs. Di Paolo, Matas, and Raymond (2017) analyzed this problem for the Metropolitan Area of Barcelona and found evidence of job-education mismatch. They show that public policies meant to reduce commuting costs could improve employment and job quality. Hensen, De Vries, and Cörvers (2009) analyzed the mismatch among Dutch university graduates using geographic distance as relevant variable. They found that graduates with higher mobility have a larger probability of having a lower chance of being over-educated in their job.

There is also some evidence of the impact of spatial mismatch in the relationship between wages and distance from home. The relationship tends to be positive since companies must compensate the transportation costs. This might be read as a favorable result in a labor market outcome, but that increase on wages has to be compensated with higher unemployment rates (Zenou, 2009). According to Dauth and Haller (2019) the relationship may be asymmetric: higher wages are required to accept an increase in commuting costs than the initial willingness to pay for a similar commuting time reduction.

the provision of fast and affordable public transport is a tool that can reduce the spatial mismatch and increase the job accessibility. Another interesting option is subsidizing private car usage. Although this has to be combined with a strong infrastructure investment, this measure might not be as popular in terms of being environmental-friendly, but it has worked better than public transport policies in places like Los Angeles (Sanchez, 2002).

Many papers have focused on evaluating the impact of these policies or the suitability of future investment on public transportation. Scholl, Mitnik, Oviedo, and Yañez-Pagans (2018) evaluated the impact of a bus rapid transit system (BRT) on employment in Lima, Perú. They found evidence of large and significant effects on hours worked, employment and monthly labor income. Martinez, Sanchez, and Yáñez-Pagans (2018) evaluated the impact of Aerial cable cars in La Paz, Bolivia. They obtained very similar results than in the Peruvian case. Moreno-Monroy and Ramos (2015) checked the impact of public transport on informality in Sao Paulo and found that informality rates decreased faster on average in the areas that received public transport infrastructure, relative to those which did not.

Measuring labor market outcomes is not a difficult task. However, measuring spatial mismatch is quite challenging. The first step to measure mismatch is to measure accessibility to jobs. Even though distance to jobs is a useful initial variable, it is incomplete because it does not include the opportunity cost of having another job, the commuting cost, the utility from different means of transportation and other variables that influence job choice and commuting. Broader accessibility measures focus on estimating the availability of opportunities, taking the supply of transportation into consideration. They have been used to evaluate social inclusion and the quality of employment (Halden, 2002). According to Oviedo, Scholl, Innao, and Pedraza

(2019) a good way to measure accessibility has to be related with time and percentage of income spent on commuting. The incidence of each of those variables depends on location.

The most famous and used formula to estimate levels of accessibility is the Hansen equation which was developed by Hansen (1959):

$$A_i = \sum_j a_j f(d_{ij}) \tag{1}$$

where A_i is the job accessibility of the zone i, a_j is the attractiveness of the zone j and $f(d_{ij})$ is a function of distance or commuting costs between i and j.

An adaption of the Hansen equation was used in Lima, Peru, by Scholl et al. (2018) to evaluate the effect of BRT system on the job opportunities. These authors found that BRT increases social fragmentation and it leads to poor labor outcomes. Even though BRT reduced travel time, commuting costs increased more than what the time travel was reduced which is something consistent with the literature that suggest regressive effects of BRT.

It is not always easy to calculate the spatial mismatch even having an equation, due to missing or not reliable data. That is a common situation in developing countries, in those cases there are some alternatives. On the last few years a usual solution is using nightlight luminosity data. Mitnik, Yañez-Pagans, and Sanchez (2018) used nightlights data to measure the impact of transport infrastructure in Haiti after the 2010's earthquake. They found evidence of improvement of the economic situation and better labor indicators due to investment in transport infrastructure trough this peculiar way to measure this situation.

3 Methodology

In this section we present the empirical approach we used to analyze accessibility. We consider three key variables to calculate our measure. Employment at a specific zone, the travel times between zones and mode of transportation.

3.1 Transport and Job Accessibility

Distance itself is not a proper measure of spatial mismatch because there are many features that cannot be captured by distance. Someone could be very far from a job, but the distance effect could be compensated by transport accessibility,high wages or other variables. Therefore, it is important to have a measure that considers several variables like travel times or distances and an opportunity cost measure for jobs in surrounding areas.

The measure we use is a Hansen equation which is an adaptation from Di Paolo et al. (2017). This measure is able to capture both transport accessibility and the opportunity cost of ignoring jobs nearby:

$$A_{i,m} = \sum_{j} \frac{emp_j}{t_{i,j,m}}, \quad t_{i,j,m} > 0 \tag{2}$$

Here, $A_{i,m}$ is the accessibility in zone i using the transport mode $m = [p, pb, w]$ representing, private vehicle, public transport and walking respectively; emp_j is the number of jobs in zone j and, $t_{i,j,m}$ is the travel time from zone i to j using transport m.

This measure is quite similar to a radio of a minute, but a radio has infinite directions, meanwhile, this measure has finite ones. It can be interpreted as the number of jobs you find per minute going to every possible zone at the same time using certain transport.

3.2 Employment

The survey we use in this paper does not provide exact information for employment at the destiny, and other data sources do not have information about this variable that includes formal and informal employment for the city at each zone. To solve this problem, we suppose that trips to work keep a proportional distribution with the real employment distribution in the city, with that assumption we can have an approximation of the spatial distribution by using the next formula:

$$emp_i = empMed * \frac{W_h * empODC_{h(i)}}{\sum_h W_h * empODC_{h(i)}} * \frac{empOD_i}{\sum_{i\epsilon h} empOD_i} \tag{3}$$

Where emp_i is the number of jobs in the zone i, $empMed$ is the total number of jobs in the whole city, W_h is the expansion factor at the commune h[1] , $empODC_{h(i)}$ is the number of trips to work at the commune h (where i belongs) and $empOD_i$ is the number of trips to work to the SIT i[2].

3.3 Travel times

We compute travel times using different methodologies for each year and transportation mode. For 2017 we computed travel times for public transport and private using Google and Bing APIs respectively. For walking, we assign travel time using the euclidean distance between zone centroids and a walking speed of 4 km/ h. Walking travel times are symmetric ($t_{i,j} = t_{j,i}$) , while public and private transport travel times are not , since routes may vary by direction of travel.

The ideal would be to compute the travel times in 2012 using the same methodology than in 2017 but, it is not possible to compute values in the past using Google or Bing, therefore for computing travel times in 2012 we used the variation on reported times from a Origin-Destination survey, this rule depends on the availability of information in each zone and it is as follows:

[1]Medellín is divided into 16 communes, each one of them is also divided in neighborhoods. Hence, a commune is a territorial unit that is bigger than a neighborhood, more information is provide on the next section

[2]It is important to clarify that we are counting just one trip to work per person.

$$t_{i,j,m}(2012) = \begin{cases} t_{i,j,m}(2017) - (Rt_{i,j,m}(2017) - Rt_{i,j,m}(2012)) & if \quad \text{There is available data in the EOD} \\ t_{i,j,m}(2017)(1 + \%\Delta\overline{Rt_i, j, m}) & if \quad \text{There is not available data in the EOD} \end{cases} \tag{4}$$

where $Rt_{i,j,m}$ represents reported times and $\overline{Rt_i, j, m}$ is the mean of reported times. As you can see in equation (4) there are two rules, the first rule applies when there is available data for a combination of zones, the second rule applies when there is not, it uses the variation of means per mode of transport.

Travel times can't be nulls due to two things; first of all, the measure does not allow travel times of 0 as you can see in equation (2) and secondly, people can go to work inside the zone they live and even if they do not, it is important to consider the opportunity cost of not working in the zone one lives.Thus, we use the next methodology to get $t_{i,i,m}$:

$$t_{i,i,m} = \frac{R_{i,outside} + R_{i,inside}}{2} * AVS_m \tag{5}$$

For each zone with a centroid, $R_{i,outside}$ is the radio of the minimum circle that contains zone i and the center is the centroid. On the other, hand $R_{i,inside}$ is the radio of the maximum circle that can be contained in zone i which center is the same centroid. To convert to time we multiply it by AVS_m, which is the average speed per minute using the transport mode m.

3.4 Adjusted Accessibility

Equation (2) allows us to compare accessibility between years as long as we have the same number of zones for each year, if the number of zones is different, a comparison of accessibility over time is problematic because the accessibility for the year with more zones will tend to be higher. you can compare between years using the adjusted accessibility measure that we propose, which is the initial measure weighted by the number of zones. Hence the new equation is defined as:

$$\hat{A_{i,m}} = \sum_j \frac{emp_j}{t_{i,j,m}} * \frac{1}{n_t}, \quad t_{i,j,m} > 0 \tag{6}$$

n_t is the sample size in the period t. For this paper $n_{2012} = 250$ and $n_{2017} = 310$ which is simply a consequence of the lack of information. $\hat{A}_i$ can be read as the average accessibility per minute in zone i going in one direction. As opposed to A_i which is the accessibility in every possible direction.

4 Data and Descriptive Statistics

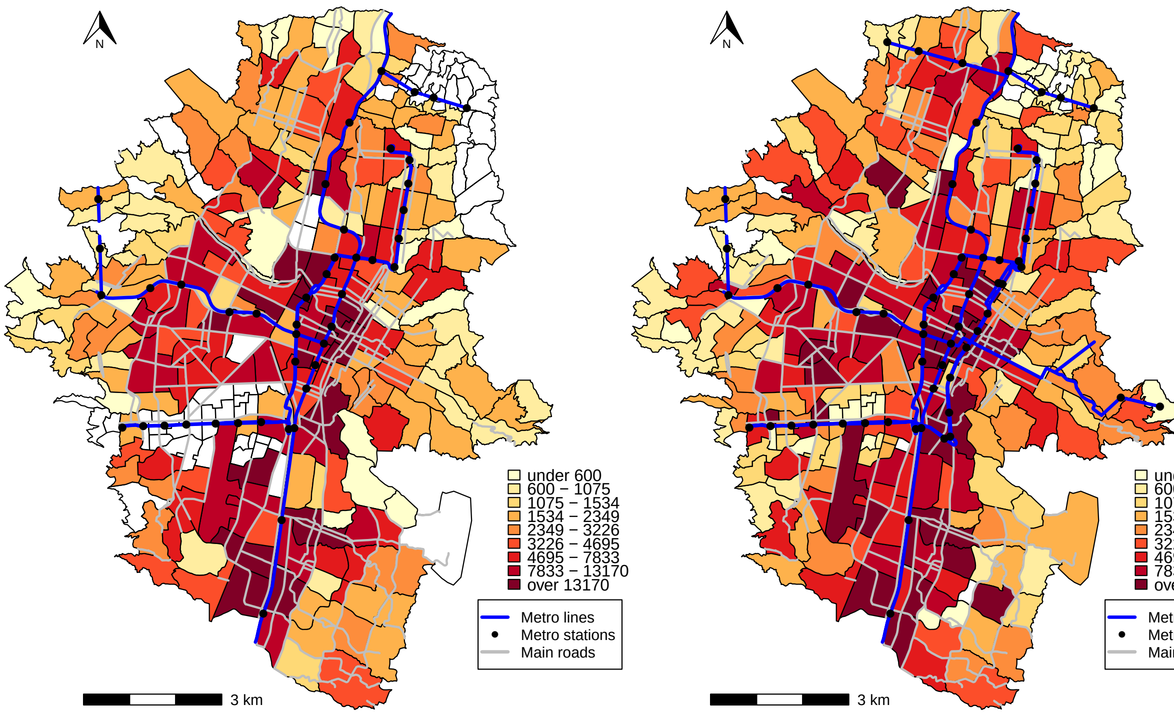
Medellín is the second largest city of Colombia. It is divided into 16 communes, each one of them is also divided in neighborhoods. There are integrated transport system zones (SIT zones) in each neighborhood. These zones can be any connection with the system. A SIT zone could be a bus station, train station, aerial cable station or others, it is basically a geographical zone where is located any kind of transport station. These SITs include all the Metro system stations. The Metro system is a rapid transit system that crosses the Metropolitan Area of Medellín in all directions, it is conformed by train, tram, an aerial cable car system and and a bus rapid transit system. In this paper our analysis zones are SIT zones.

Our travel data comes from the Origin-Destination survey (EOD, for its acronym in spanish, “Encuesta Origen-Destino”) of Medellín for the years 2012 and 2017. This survey provides information about travel times and trips in Medellín and The Metropolitan Area. It has self-reported travel times and geographies for the SIT areas or zones. It is possible to have a better approach to the travel time using a Google API or any other source, because the self-reported times are subject to measurement error. This paper uses times from Bing for private vehicles and Google for public transport but, as we mentioned before at some point we have to use reported travel times. Still, this is an improvement since people tend to underestimate and round out travel times (Carrion & Levinson, 2019).

We also obtain from EOD a measure of employment by destination. we count the number of trips that arrive at each destination and are labelled as commutes. We then assign city employment to each zone using equation (3).

To start, we give a picture of how employment is distributed in the city by plotting the spatial distribution of the employment which was calculated using the equation (3). In Figure (1) we observe that employment density for both years is concentrated in the south and center of both maps which is expected because the center is the most commercial area of the city, moreover, the south of Medellín keeps the industrial zone and a considerable amount of financial and entertainment services.

Additionally, the distribution did not have a noticeable change from 2012 to 2017 in most of the city. However, there is a slight increase on density that follows the new Metro system lines, we can see it on the east, center and northwest of the map for 2017. According to the national department of statistics (DANE) during those 5 years, employment increased from $1'665,000$ to $1'799.000$. which is an increase of 8%. It is necessary to comment that there is not possible to get information of jobs for all the SIT zones, as we can see, there is more available information for 2017 than for 2012.



(a) Employment 2012

(b) Employment 2017

Figure 1: Spatial employment density distribution in Medellín

Source: EOD of Medellín 2012-2017 and authors' calculations.

For an initial idea of how accessible jobs can be in terms of transportation, it is interesting to look at the mean of the reported times and its difference, we can see that in table 1.

Table 1: Reported travel times in minutes

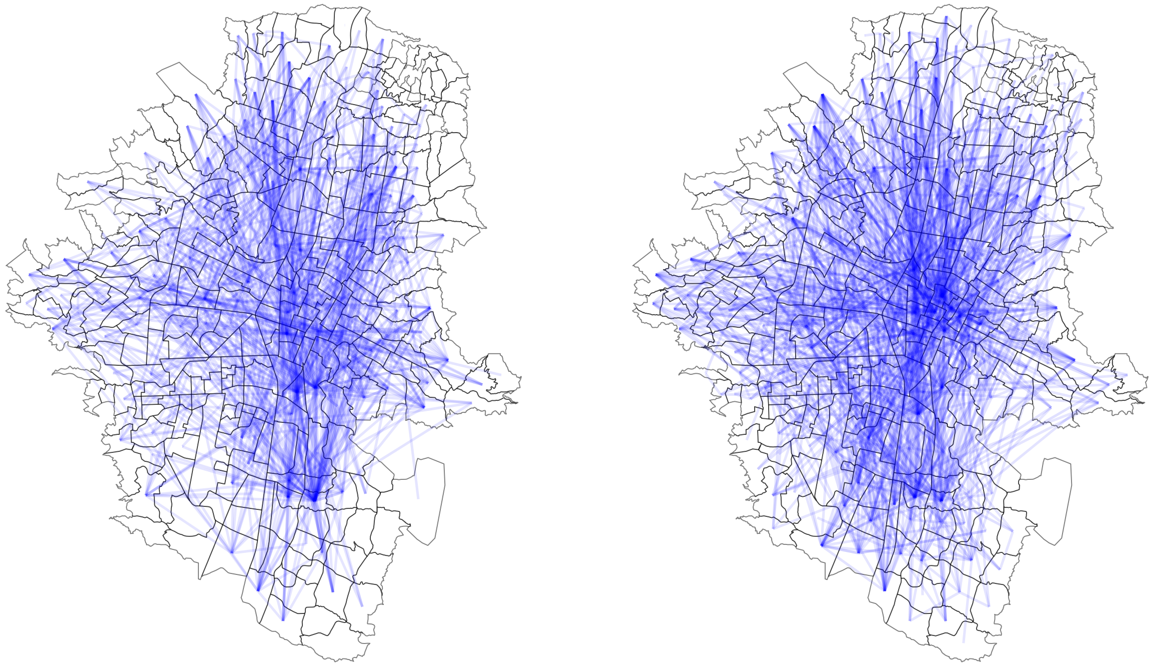
Transport	Mean 2012	Mean 2017	Diff Means	%Diff Means
Public	44.03	50.19	6.16	14.0%
Private	27.96	32.71	4.75	17.0%
Walking	15.32	18.43	3.11	20.3%

Source: EOD of Medellín 2012-2017 and authors' calculations.

Note: Travel times are per individual, the trips counted are strictly to work and we are taking just one trip per person. In the first two columns we present the mean and in the last ones we present the difference of means and the difference of means in percentage respectively.

As you can see in table (1) reported times increased for all transport modes, this increase can be considered significant and in the results we can check the relationship between this increase and the employment increase through equation (2). However, in the case of walking there is not enough evidence in real life to support this increasing difference of means, it could just appear as the result of sample selection.

After presenting some evidence of employment distribution and travel times, we consider important to take into consideration where people go.



(a) Desire lines-2012

(b) Desire lines-2017

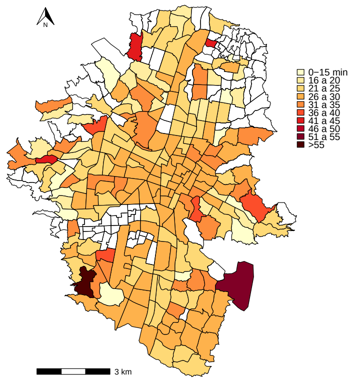
Figure 2: Desire lines for 2017 and 2012

Source: EOD of Medellín 2012-2017 and authors' calculations.

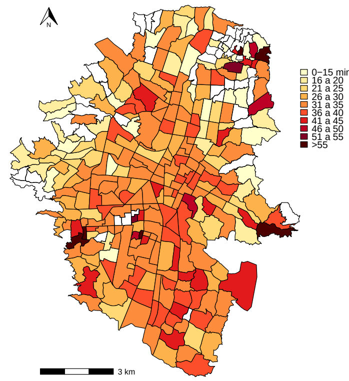
Note: In order to get a clear picture of the trips, it considers combinations of trips which are repeated two times or more. Each line has an origin and a destiny.

Figure (2) shows the movements of people among different SIT zones for 2012 and 2017. It indicates that most of the trips are going to the center and the south of the city, this distribution does not seem to change during the years. actually, this is consistent with the employment distribution. There is a positive association between trips and jobs. Accordingly, it is especially relevant to analyze the evolution of mismatch in those zones. However, the density of the trips seems to slightly increase in 2017 as can be seen in figure (2b).

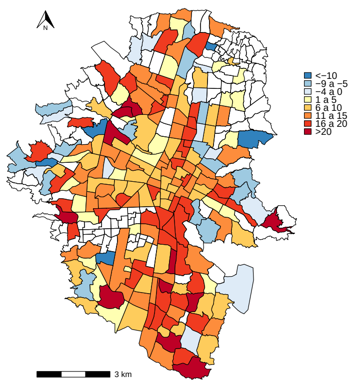
We already know where people go, but how fast do they get where they go? Figure (3) presents this information.



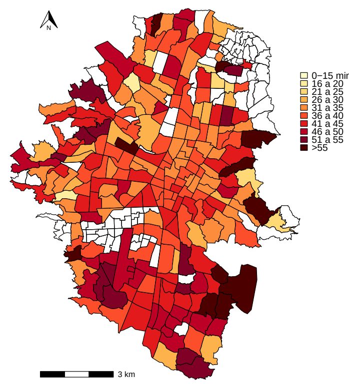
(a) Reported private times-2012



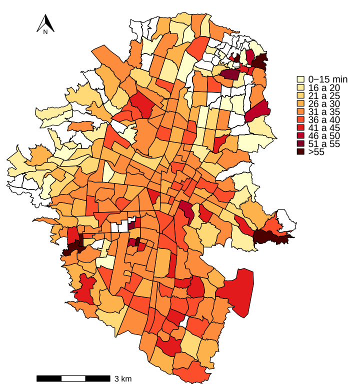
(b) Reported private times-2017



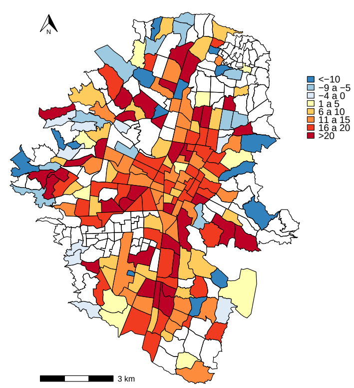
(c) Difference of reported private times



(d) Reported public times-2012



(e) Reported public times 2017



(f) Difference of reported public times

Figure 3: Reported Destination times 2012-2017 in minutes

Source: EOD of Medellín 2012-2017 and authors' calculations.

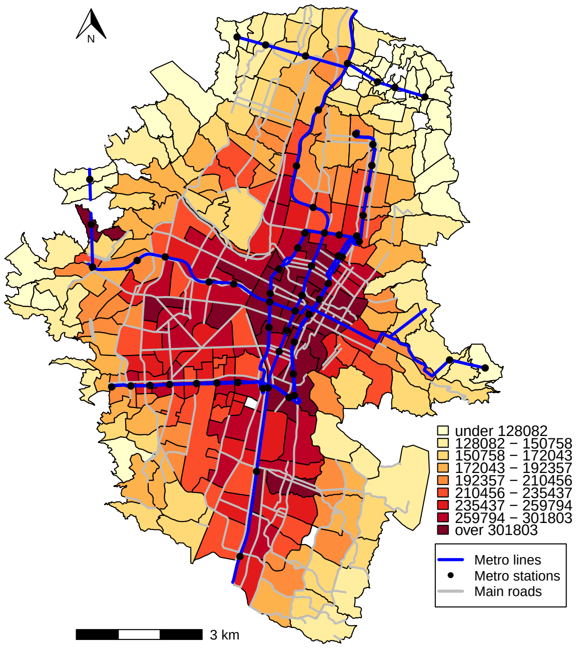
It shows the information of the average reported travel times for each destination for public and private transport. It tells us how difficult is to get to a zone using private or public transport. As can be seen, reported travel times increased for the majority of zones. That difference is represented by the red-yellow color in the differences graphs. Additionally, it seems that those travel times do not follow any pattern. To get more information about how easy or difficult is to get or leave a zone, check the Appendix (6).

5 Results

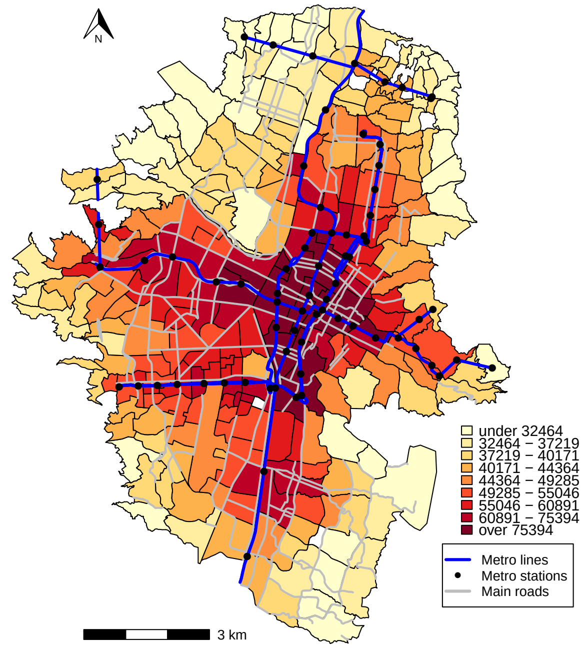
In this section we present the calculation of the spatial mismatch measure. Our empirical approach is based on the assumption that there is always spatial mismatch. This assumption is reasonable if we take into consideration the mechanisms presented by Gobillon et al. (2007). In fact, there is always a cost associated with going to work as long as the 100% of the jobs are not at home. There is also a negative relationship between our measure and the mismatch, since accessibility means faster transportation or more jobs close by. Thus $A_{i,m}$ is inverse to spatial mismatch.

5.1 Comparing years and modes of transport

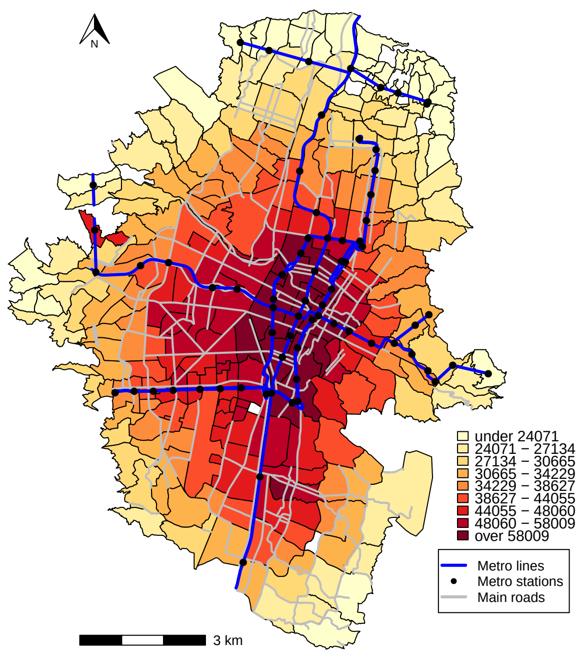
The graph below represents the results we obtained for $A_{i,m}$ using the three means of transportation during 2017. Figure (4) shows as expected that zones with high employment density also tend to have high accessibility which represents a lower mismatch. An additional important issue is the distribution of accessibility for public transportation, we can see how in many areas public transport accessibility strongly follows the Metro system. Therefore, figure (4b) gives us an initial idea of how dependent the Metro system and the public transport in the city are. For walking, since we used the euclidean distance and a speed of $4km/h$, figure (4c) shows a strong concentration in the center of the map. SITs on the center are smaller and its distances are easy to cover by walking, Moreover, they have a high employment density.



(a) A_i private-2017



(b) A_i public-2017



(c) A_i walking-2017

Figure 4: Accessibility measure 2017

Source: EOD of Medellín 2012-2017 and authors' calculations.

A preliminary look at figure (4a) shows considerably higher numbers than figures (4b) and (4c). To get a better approach table (2) shows detailed statistics.

Table 2: Transport and Job accessibility

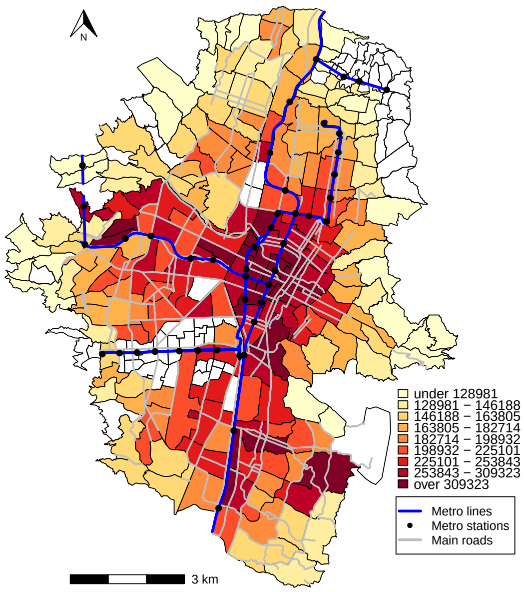
Modes of transport	$\bar{A}_{2017}$	$\bar{A}_{2012}$	$sd(A_{2017})$	$sd(A_{2012})$	$\overline{\hat{A}}_{2017}$	$\overline{\hat{A}}_{2012}$	$Diff(\overline{\hat{A}})$	$\%Diff(\overline{\hat{A}})$
Private	$214,468.9$	$219,472.8$	$88,741.2$	$118,922.1$	691.8	881.4	-189.6	-21.5%
Public	$50,905.6$	$81,357.7$	$18,043.5$	$90,992.2$	164.2	326.7	-162.5	-49.6%
Walking	$39,807.6$	$39,311.4$	$15,673.1$	$16,552.5$	128.4	158.5	-30.1	-18.9%

Source: EOD of Medellín 2012-2017 and authors' calculations.

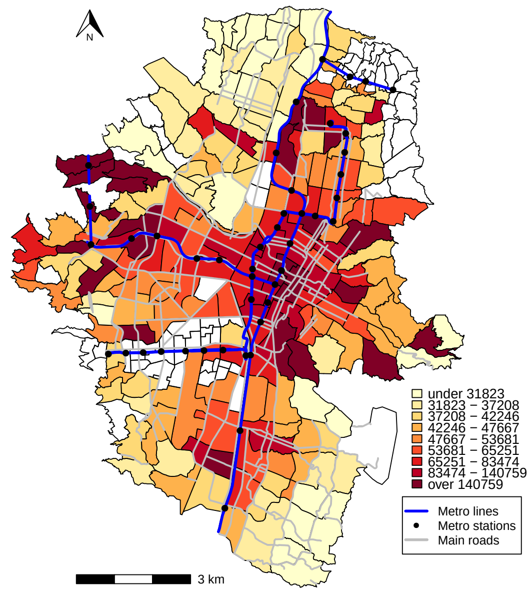
Note:On the first 4 columns from the left we present results for the average accessibility and its standard deviation using equation (2). the last 4 columns offer information of the average adjusted accessibility obtained from equation (6) by year and its differences. Since this measure can be compared between years, it is interesting to analyze the differences.

As can be seen, accessibility using private vehicles is considerably higher. $\overline{A}_{2017}$ can be interpreted as the quantity of jobs in the radio of 1 minute, a more intuitive interpretation is given by the adjusted accessibility which will be analyzed later. Then, the accessibility in one specific direction in private is transport 4.2 times the accessibility in public transport. We can also identify a high value for walking which is even close to public transport. Unfortunately, this value is probably overestimated due to the lack of information and the use of the euclidean distance which does not consider real walking routes, waiting times to cross streets and speed variations related with the traffic of people.

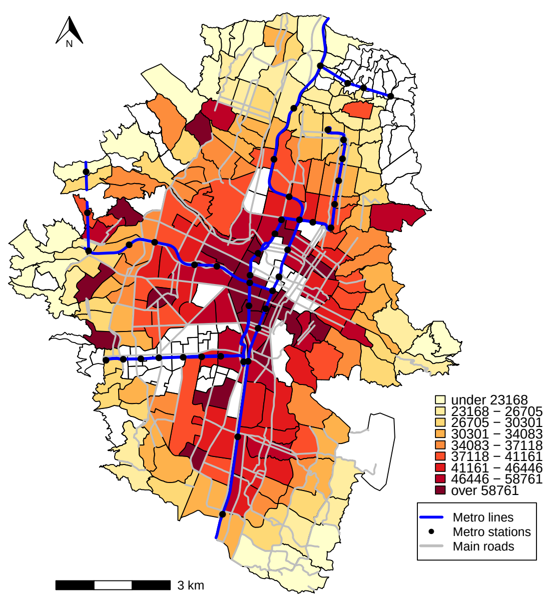
Results for 2012 are presented on the figure below, the maps we use were obtained following the strategy we adopted in equation (4). As we can see, there is not a big difference with 2017 in terms of distribution. However, in figure (5b) since there were less lines of the metro system, accessibility seems more concentrated in other zones such as the northwest, where the areal cable is. Hence it seems that Metro system can slightly impact the accessibility distribution.



(a) A_i private-2012



(b) A_i public-2012



(c) A_i walking-2012

Figure 5: Accessibility measure 2012

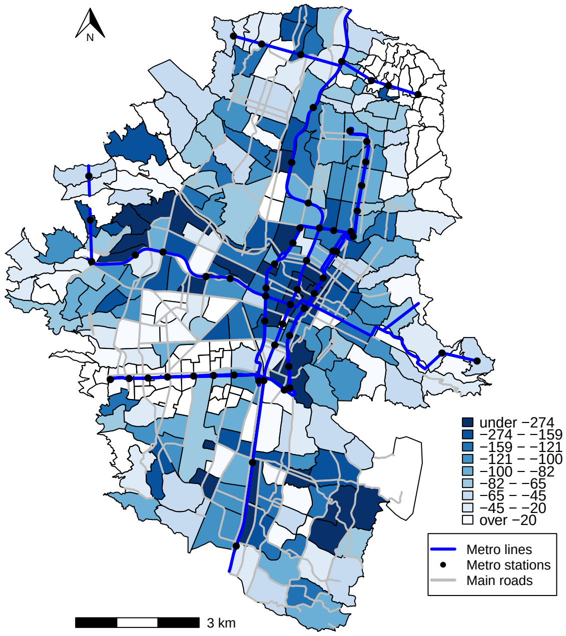
Source: EOD of Medellín 2012-2017 and authors' calculations.

These values keep a similar pattern with respects to 2017 case, private transport brings far more accessibility than public transport and walking. Also, for both years there is a considerably high volatility in both measures, which is reflected in the standard deviation, however, this is something you could expect from the nature of this measure since there are plenty of areas with high employment concentration and there are also areas far more accessible than others. In addition, we have to consider that standard literature shows that people tend to underestimate reported times and we calculated these times using equation (4).[3] Even though we used reported times, average accessibility is bigger in 2012 than 2017 as we are going to explore in the next section.

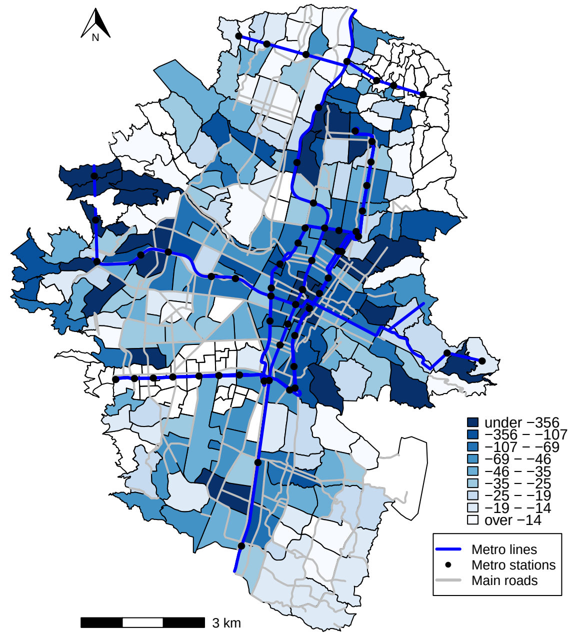
To compare both measures for 2012 and 2017 we can not do it directly since we have different number of SIT zones with available information for both years. In order to be able to compare them, we analyze the evolution of the adjusted accessibility which is an inverse measure of the average mismatch per zone. Thus, we compare $\overline{\hat{A}}_{2017}$ and $\overline{\hat{A}}_{2012}$, where $n_{2017} = 310$ and $n_{2012} = 250$.

Figure 6 shows that average accessibility has decreased from 2012 to 2017, in fact it decreased for all the zones where we have information. Employment from 2012 to 2017 increased 8%, but even considering the increasing employment, the effect of the increasing travel times leads to lower accessibility in 2017.

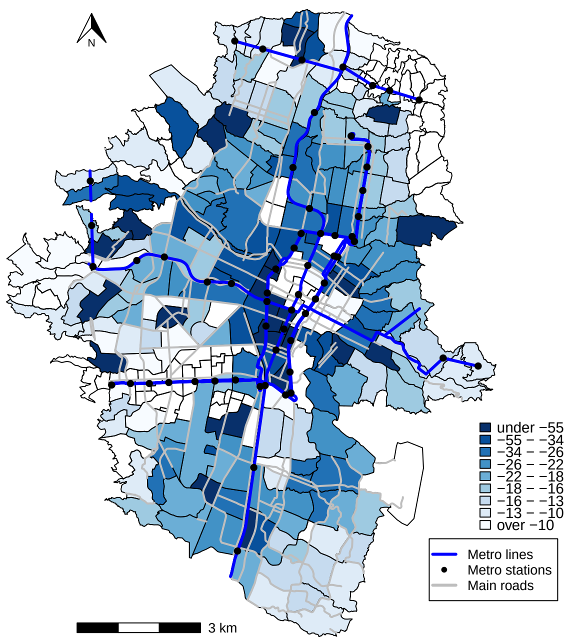
[3] Carrion and Levinson (2019),Rietveld, Zwart, Van Wee, and van den Hoorn (1999) and Li, Rose, and Sarvi (2006), among others defend this idea, mainly for short distances such as distances at a intra-urban level



(a) A_i Private



(b) A_i Public



(c) A_i walking

Figure 6: Difference of Adjusted Accessibility between 2017 and 2012 per SIT zone

Source: EOD of Medellín 2012-2017 and authors' calculation.

We can see that there is not evidence of an increase in accessibility of areas close to the new metro lines developed from 2012 until 2017. At most, we could speculate that the new metro lines slow down the decreasing accessibility in specific zones. However, looking at figure 6b we can see that public transport accessibility is decreasing faster than private and walking which leads us at some important conclusions that are mentioned in the next section.

Table (2) supports the evidence of an increasing mismatch in Medellin. Actually, public transport holds the higher adjusted difference between means. This parameter can be interpreted as the number of jobs per minute in one direction. For example, for private transport in 2012 you could find in average 881.4 jobs per minute, while in 2017 you could find 691.8 jobs per minute. Which is consequent with the increasing reported travel times.

Another interesting result to observe is the evolution of the accessibility gaps between public transport and private for both years. In 2012 the gap was 554.7 while in 2017 the gap was 527.2. Even though accessibility for any mode of transport has decreased, the gap between public and and private has decreased about 5% which slightly support that idea of that investing in public transport helps to slow down the increasing mismatch in the city.

6 Conclusions

In this paper we focused on analysing the spatial connectivity to jobs at the intra-urban level trough different modes of transport. We specifically analyzed the case of Medellín where there has been an important effort to bring a better public transport and infrastructure. From 2012 to 2017 the metro system expanded its operations with new bus lines like the Metroplus[4] line 2 in 2013, a new tram in the center of the city in 2016 and a new aerial cable route.

[4]The metro system bus rapid transit system line

Independently of the efforts, it is clear that for both years 2012 and 2017 the accessibility obtained in private vehicle is superior than in public transport, the gap was reduced in a small proportion in 2017 but, it is not enough sustain for a premise of positive relationship between accessibility and public transport investment in Medellin. In fact, it seems that currently having a car or a motorcycle is a better option for going to work that using public transport. This evidence could be also important in terms of environmental policies, it justifies that individuals do not have incentives to use public transport since it seems to be strongly more inefficient.

The spatial mismatch between 2012 and 2017 increased indistinctly, increasing by a faster proportion for public transport. This increasing mismatch could not be relieved by the increasing employment density. The evidence from this paper suggest that each year seems more difficult to get a job in a far away location, and those jobs imply rising costs in terms of travel times.

Despite of the limitations of this paper, we think that public transport and road infrastructure policies have not had the expected effect on the mismatch in the city. The increasing traffic, the waiting times and the impossibility of expanding many routes keep the accessibility stagnant. Therefore, it is important to approach this problem from a different perspective, to avoid commuting costs and the opportunity cost of the travel times, policies focused on telecommuting should have more relevance. Additionally, when there is necessary the mobilization of people, policies of social mobility and housing about the industrial zones could be considered. Urban planners and policy makers should consider that having access to a private vehicle in Medellín is more efficient in terms of accessibility and that public transport policies by themselves have not had a noticeable impact on the accessibility.

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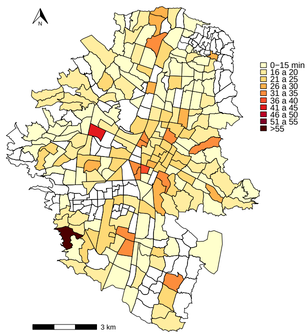
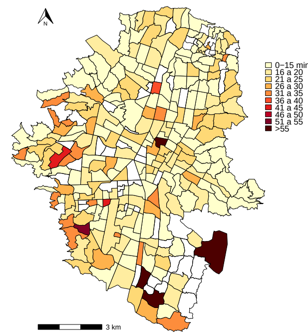
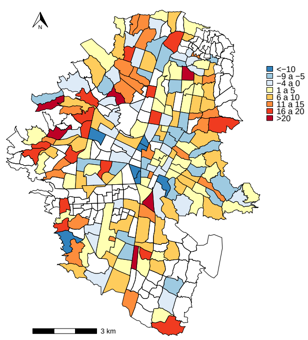
A Walking reported times



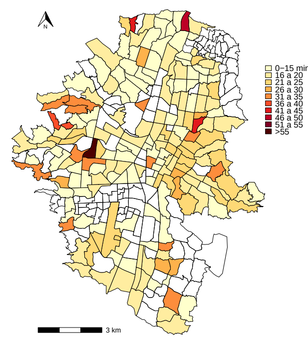
(a) Reported walking destination times-2012



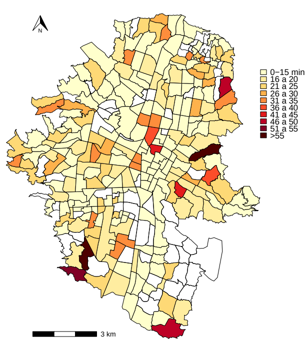
(b) Reported destination times-2017



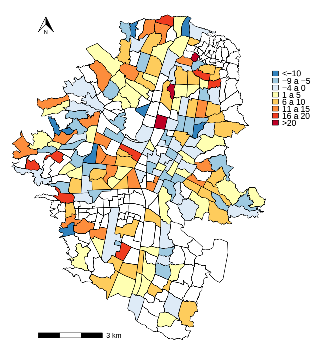
(c) Difference of reported walking times at destiny



(d) Reported walking origin times-2012



(e) Reported walking origin times-2017

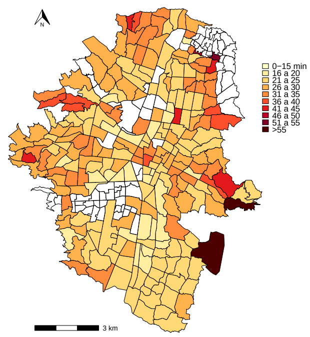


(f) Difference of reported walking times at origin

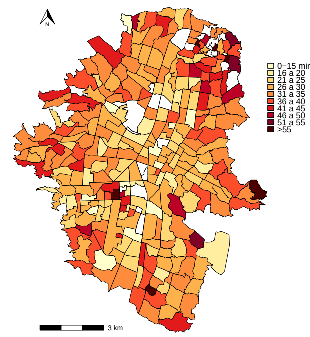
Figure 7: Reported walking times 2012-2017

Source: EOD of Medellín 2012-2017 and authors' calculation.

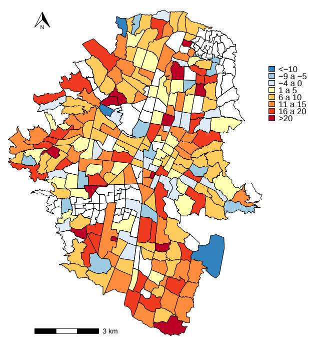
B Private and public transport reported times at origin



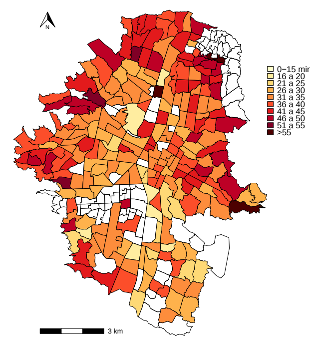
(a) Reported private origin times-2012



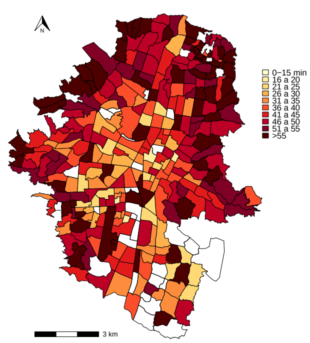
(b) Reported private origin times-2017



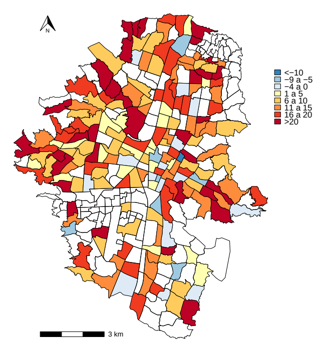
(c) Difference of reported private times at origin



(d) Reported private origin times-2012



(e) Reported walking origin times-2017



(f) Difference of reported public times at origin

Figure 8: Reported private and public times 2012-2017 at origin

Source: EOD of Medellín 2012-2017 and authors' calculation.