Bogota's Bus Reform Process: Accessibility & Affordability effects, Lessons Learnt & Alternatives to Tackle Informal Services

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ABSTRACT

Many cities in the developing world are embarking on transit reforms aimed at capturing user and nonuser benefits through the formalization of bus services. Bogotá was a forerunner in this reform process, first with the implementation of the Transmilenio Bus Rapid Transit system, and more recently with the large scale initiative to formalize and regulate the city's traditional urban buses. With this Integrated Public Transport System(SITP), Bogota's traditional urban buses are being transformed into a regulated, concessioned system with restructured bus routes, and operational, fare and infrastructure integration with Transmilenio's BRT. In this paper, we study if the SITP resulted in employment accessibility and affordability gains for public transit users in Bogota. Our findings revealed that most of the changes in accessibility result from the recent expansion of Transmilenio and its significantly higher speeds, as opposed to any significant gains from the SITP. In terms of affordable accessibility, adding a budget threshold reduces the overall employment accessibility in the city; however, the new integrated fare increases accessibility compared to the traditional buses, especially in the periphery and the southern areas of the city due to reduced transfer costs. These results partly explain the lack of enthusiasm about the bus reform process from public transit users and the political discomfort in cities of the developing world with embarking on this process. The paper uses these results to suggest ways in which a more incremental, flexible and technology enabled reform could be crafted for public transportation systems dominated by atomized informal services.

Keywords: accessibility, affordability, bus reform, Bogota, remote sensing, open-data.

INTRODUCTION

Many cities in the developing world are embarking on transit reforms aimed at improving and formalizing bus services. One the one hand, the impetus of this reform process is driven in many cities by the need to address the negative externalities generated by the largely informal and unregulated bus system— congestion, traffic-related accidents, GHG and local pollutant emissions. On the other, many reforms are in principle driven by the notion that restructuring the supply, applying stricter quality control and more efficient enforcement and regulation will ultimately result in meeting passenger needs in terms of improved accessibility, reliability, affordability and safety. Cities are also scaling up bus reforms, from corridor-specific projects (including Bus Rapid Transit, BRT) to city-wide integrated systems.

Bogotá was a forerunner in this reform process, first with the implementation of the Transmilenio BRT system, and as of recently with the large scale initiative to formalize and regulate all of the city's traditional urban buses, under a project called the Integrated Public Transport System (*Sistema Integrado de Transporte Público,* SITP). With the SITP, the city's traditional urban buses are being transformed into a regulated, concessioned system with restructured bus routes, and operational, fare and infrastructure integration with Transmilenio's BRT system.

This paper presents a critical analysis of how employment accessibility and affordability changed as a result of Bogotá's SITP. The paper describes the main features of Bogota's bus reform process, and analyses how employment accessibility changed before and after the implementation of the SITP. Accessibility offers a powerful lens to assess how a mobility system is serving an urban area, and to understand the impacts of different transportation projects or policies, in this case the effects of the SITP. For this, we perform an innovative accessibility analysis using the Transport Analyst tool to provide a high-resolution detailed study of local accessibility changes, as well as include an affordability lens into the assessment of the SITP to estimate accessibility given a budget constraint. The results of our analysis suggests that most of the accessibility gains in Bogotá over the two time periods are related to travel time savings generated by the Transmilenio system; accessibility gains from the SITP—the reform and integration of the zonal bus system—are meager or nonexistent. Adding a travel budget constraint (i.e. affordable accessibility) reduces the overall employment accessibility, however the new integrated fare increases the accessibility compared to the traditional urban buses, especially for population living in the city's periphery. These results partly explain the lack of enthusiasm about the bus reform process from public transit users and the political discomfort in cities of the developing world with embarking on this process. The paper uses these results to suggest ways in which a more incremental, flexible and technology enabled reform could be crafted for public transportation systems dominated by atomized informal services.

The first section of this paper describes Bogota's SITP. The second section presents the socio-demographic spatial patterns of the city, the transport spending, travel patterns, and provides the methodology used to calculate accessibility and affordability. The third section describes the differences in accessibility in Bogota over two different time-periods: before and after the implementation of the SITP. The fourth section discusses some of the lessons learnt from Bogota's bus reform process. The paper concludes with some initial ideas on how more incremental, flexible and technology enabled reform could be adopted to tackle informal services.

BOGOTA'S INTEGRATED PUBLIC TRANSPORT SYSTEM

Until the development of the Transmilenio system in 2000, all public transportation in Bogotá was operated under a system characterized by an inadequate incentive structure that led to an oversupply of buses, increased congestion, reduced vehicle safety and low quality service. Bus companies owned the routes granted to them by the city government but were not required to own the bus fleet. Individual investors owned buses, and bus companies rented out to bus owners the right to operate a certain route. This arrangement induced bus owners to compete against other buses, irrespective of demand patterns, as their revenue and the wage of the bus driver was directly related to the number of passengers carried. Bus companies' main assets were their routes as they rent them out to bus owners, so they had the incentive to lure as many buses as possible to operate their routes. The incorporation of a number of buses beyond those required to serve the market led to excessive competition, locally known as "the penny war" (*guerra del centavo*) because drivers literally fought for each prospective passengers(1).

In response to these shortcomings, by the end of the 1990s, the government of Bogotá began to explore alternative ownership models and incentive structures that maintained the benefits of privatization but improved service provision. One such ownership model was concession contracts for service provision. In this system, a competitive bidding process is used to determine which bus operators will have the right to operate a route or a number of buses. The concession is for a limited period of time, which ideally coincides with the useful lifespan of the fleet, as opposed to the lifetime permits offered in the traditional model. Bus operators, in turn, need to own the bus fleet and operate it under close supervision and regulation from the public sector, which determines whether operators supply the scheduled service. On the infrastructure side, the system uses exclusive bus ways, high-capacity buses, a centralized fare collection system based on the use of smartcards and a fleet control system(2). This new ownership model, incentive structure and infrastructure provision was at the crux of the Transmilenio BRT system, implemented in Bogotá in December 2000, which currently represents approximately 30% of the city's public transit trips.

In late 2010, Bogota embarked on a city-wide reform process aimed at formalizing and regulating the remaining bus-based transit services, under similar competitive concession arrangements for service provision that were implemented under Transmilenio. In this scheme, zonal buses are paid on the basis of number of fleet in operation, cost/kms logged and passengers carried, over a 24 year concession period. The SITP was designed to have an integrated operation, infrastructure and fare (payments would be made with one smart card) between zonal buses and the Transmilenio BRT system, and in the future, with Bogotá's first subway line. Currently, the fare structure is as follows: COP1,700(approx0.55USD) for zonal buses, COP2,000(approx0.65USD) for the BRT, and transfers between services are only COP300(approx0.10USD) within a 75minute time window.

For this purpose, the city was divided into 13 zones that could be served by 9 different operators (each zone could be served by more than one operator), 2 of which represented small incumbent bus owners. Incumbent bus owners could either participate as shareholders in the new operating companies, or could be compensated by selling their bus or by renting them out to new operating companies until the end of the fleet's lifecycle (equivalent to receiving a monthly rental income for their fleet for the duration of the concession period); almost 80% of incumbents decided to opt for a monthly rental income. In 2010 traditional bus owners and bus drivers went on strike, calling for greater compensation as a result of the SITP. Thus, the operation concession period was extended from 12 to 24 years; monthly rental rates increased from 10% to 18% annual return and bus sales price increased by 5%. As part of the concession

terms, new operating companies also committed to scrap almost 9,000 old buses, and to the early retirement of vehicles. All of these costs related to compensating the incumbent or bus scrapping indirectly became part of the bus operating costs of the new companies established, and are ultimately paid for by the user via the bus fare.

For an operational perspective, the SITP required the reorganization and optimization of the traditional bus system so that a multimodal integrated system could operate. The new Operational Design entailed a revision of the total number of routes, its timetables, headways and fleet type, so that demand could be served in a more efficient manner. The city's nearly 700 bus routes and more than 16,000 traditional urban buses were transformed into 450 routes, a fleet of almost 10,000 buses, 6700 bus stops, and 4600 smartcard recharge points. Also note that the system was not designed exclusively as a trunk-feeder network; in effect, less than 10% of trips require a transfer.

Bogotá also opted for a gradual implementation of the SITP, as opposed to the "Big Bang" approached followed in cities like Santiago, with the TranSantiago system. Although this gradual implementation should have been completed by mid-2014, implementation was met by numerous challenges, and as of today only 80% of the system has been implemented. The implementation did not happen as was planned and many obstacles were faced by the bus operators, fare collection company and the city—users complain about the long routes and low frequencies of the new system, the complexity of the route nomenclature and services offered, the lack of smartcard selling points and recharge network, the low capacity of Transmilenio S.A (implementing agency) to monitor and control in real-time the services provided by private operators, and the dire financial situation of some operators. In particular, the two operating companies representing most of the small incumbent owners and almost 30% of the SITP demand went bankrupt, and Tramsilenio S.A had to take over operation in these zones, and is structuring how they will operate. All in all, key assumptions that drove the SITP's conceptual design have not been met—demand was estimated at almost 6million daily trips (demand is closer to 5mll), passenger per km index of 2.6 in zonal buses (in reality 1.3), commercial speed of 17km/hr (in reality 13km/hr); users complain about the quality of service provided by the SITP, leading to a substantial deficit and fiscal commitments from the city, and the proliferation of illegal transport.

ACCESSIBILITY METHODOLOGY

The analysis presented in this paper uses three key inputs: spatial distribution of population, employment and poverty, mobility patterns and the digital public transport system before and after the SITP, including the new integrated fare structure.

Population

The city of Bogota covers 341 km^2 of urban land and has more than 7.8 million residents according to the 2013 Census, making it one of the densest cities in the world. The population is divided unequally between its 112 urban planning units (*Unidades de Planeamiento Zonal*, UPZ), with density ranging from 56,000 pp/km^2, usually in lower income areas; to other generally higher-income areas, with a density between 6,000-15,000 pp/km^2.

One of the purposes of this research however was to have a high resolution and localized understanding of city accessibility and affordability; therefore, we used WorldPop(3) to complement the data from the 2013 Census. WorldPop disaggregates census population counts within subnational administrative boundaries by modeling likely residence locations at 100-meter scale. The model used by WorldPop, Random Forest Classification and Regression, employs a Machine Learning approach that is robust to outliers and noise.

Using the high-resolution data from WorldPop, we defined each grid square as an origin for the accessibility model, which provided a detailed, local picture of accessibility and affordability.

Employment & Remote Sensing Data

Employment data was obtained from Bogota's Secretariat for District Planning for the update of the city transport model. There are approximately 1.68million formal jobs and 1.77million informal jobs in the city in 2011(4). As for the location of jobs, a highest concentration is observed in the expanded central business district of the city, and decreases as it moves away from the center. This high concentration of jobs in specific parts of the city has caused major problems of unequal transit access that affects primarily the low-income population(5).

In order to produce local employment maps, we used high-resolution Earth Observation(EO) to determine the location of attraction areas in the city. Working with the European Space Agency (ESA), 1-meter (MMU 0,25ha) resolution satellite imagery was processed to extract every single building, structure and vegetation of the city. The extraction process produces 23 different classes corresponding to the Urban Atlas (GMES)/European CORINE nomenclature.

In order to use these land classes to disaggregate employment, we worked with data from Lima to run a regression analysis correlating land class type to employment density. In Lima, we have employment data at the building level, which matched the building outputs from the derived imagery form the EO data. The regression analysis allowed us to determine the coefficients with which to later disaggregate the UPZ data in Bogota. Once the land classifications for green urban areas, sports and leisure facilities, mineral extraction and dumpsites, roads, and water areas have been removed, the linear regression produced an r-squared of 0.832.

Using the coefficients for land classifications derived, we were able to disaggregate employment from the UPZ level to the building equivalents derived from the EO outputs.

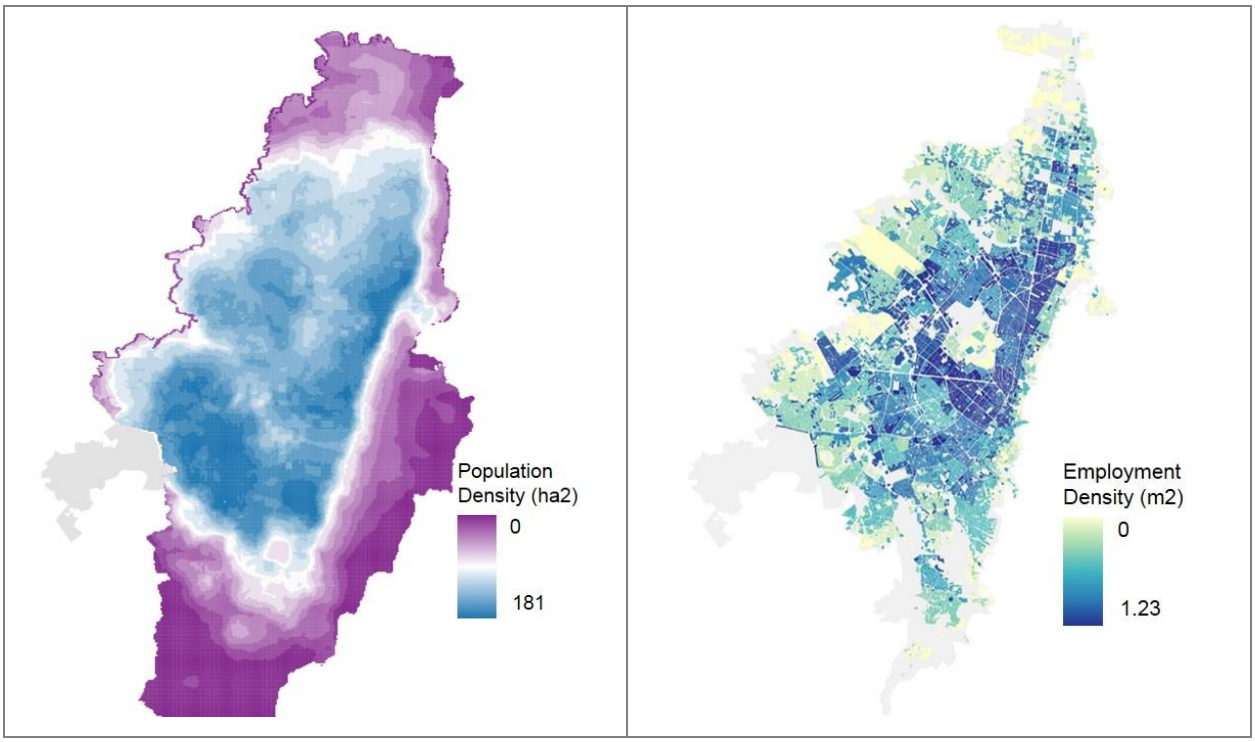

FIGURE 1 High resolution population (left) and employment (right) for Bogota.

Poverty and Transport Spending

In terms of socio-economic distribution of population, the last census indicates that most of the low-income population in Bogota lives in the periphery of the city, particularly in the southern and western parts of the city. The evidence shows that in 2011 66% of the households in Bogotá belong to the lowest income ranges, with a household income of less than USD680.

The average percentage of individual monthly income spent on transport in the lowest income group exceeds 20%(5) reaching up to 28% in some parts of the city(Figure 2), well above the internationally acceptable level of affordability, 15%(6).

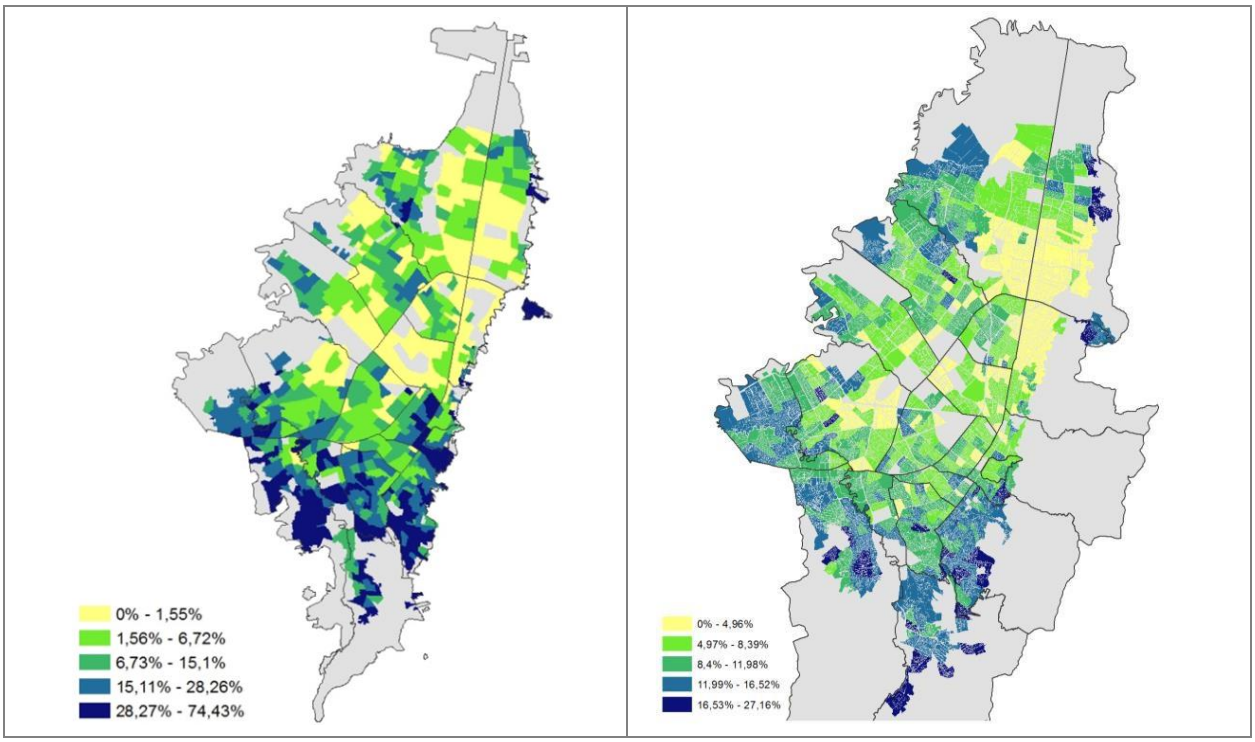

FIGURE 2. Percentage of population in lowest income strata (right) and public transportation spending as a Proportion of total household expenditure -- Source: Bogotá Multi-Purpose Survey, 2014.

Travel Patterns

The data used to determine commuting patterns was provided by the Bogota Mobility Survey *(Encuesta de Movilidad*), performed in 2011. In Bogota, the Transmilenio and bus system carry more than 60% of motorized trips. Automobiles have the second largest share of trips, carrying 20% of motorized trips. The average travel time for a work trip in Bogota is almost 63 minutes. Travel times for the lower income trip-makers is almost double than those for the highest income: for those in the bottom income quintile travel time is on average 77-minutes while for those in the highest it is 40-minutes(7).

Transport Model

In order to model the transit network, we used the four-step VISUM model developed by the Universidad de los Andes. This model has been maintained over the last 8 years with up-to date geo-referenced information for each transit route. The model was used to calculate the travel speeds on the road of transit routes that use the road network. The model indicates that the average speed for the traditional buses was 12.1km/hr, while the SITP average speed increased to 13.7km/hr. The average speed for Transmilenio in 2011 was 28.6km/hr, and increased to 32.5km/hr by 2015.

Accessibility and Affordability

This research builds upon the paper of Peralta and Mehndiratta(8), that used a definition of employment accessibility as the amount of labor opportunities that can be accessed in a given threshold using non-private modes.

Building on traditional accessibility measures(9,10,11,12) the Isochrone model(13) takes into account the total number of opportunities that can be reached within a given time, distance or cost threshold. This model uses a binary threshold to determine accessible opportunities, as follows:

$$Accessibility_i = \sum_j Opportunities_j W_j \quad (1)$$

Where

i=origin
j=destination
Wj = 1 if Cij < Cij; 0 otherwise*
Cij = travel time (or cost) from i to j
*Cij * = travel time (or cost) threshold*

The Transport Analyst is used to calculate the accessibility. This tool uses the public transport network and attributes (frequencies and speeds derived from the VISUM model), to calculate the travel times from every origin destination pair in the city. The tool then combines the estimated travel times and location data for employment opportunities to calculate the accessibility value for every point in the city.

In recent years, this definition of accessibility has been used to explore land-use and transport trends in US settings(14), and has more recently been expanded to cities globally. Previous research however, has focused on studying regional accessibility and studying large land-use patterns and transport. The purposes of our research were to provide a detailed, high-resolution accessibility analysis of the effects of different transport scenarios.

In order to calculate affordability we built upon this model by adding another binary threshold to the equation that used the cost of the trip. Therefore, we consider to be accessible and affordable only the opportunities that are within a given trip time and cost.

ACCESSIBILITY & AFFORDABILITY IN BOGOTA BEFORE & AFTER THE SITP

We used this high-resolution data and methodology to estimate the differences in accessibility and affordability in the two different time-periods, before and after the implementation of the SITP(2011-2015). We used a 60-minute travel time as the travel threshold, which captures most employment commutes, and has been used in multiple settings as the standard for employment accessibility(15).

The figure below displays the accessibility results before and after the implementation of the SITP. In both time-periods a large portion of the population that lives in the city center can access a large share of Bogota's employment opportunities— between 76.3%-97.9% of all employment— this accessibility largely correlates with the Transmilenio BRT network, which is shown in both figures. This result is both consistent with the fact that most employment opportunities in Bogota are concentrated in the expanded central business district, and that the highest-income population lives in this boundary. The striking result is that save for the accessibility gains in the central western zone of Bogotá —related to the construction of a new Transmilenio BRT line— there are no major gains in accessibility as a result of the SITP; particularly for people living in the southern and western periphery of Bogotá, where most of the low-income population lives.

The employment accessibility changes (Figure 3, to the right) show significant changes over the two periods around certain Transmilenio BRT Terminal Stations. Particularly, some of the locations around the southern corridor (Portal Sur) and western corridor (Portal El Dorado along the 26th Avenue) increased accessibility by 39.8%-91.1%. The city center, as expected, does

not display significant changes in accessibility, since this area has always enjoyed good accessibility. It is evident from these results that the majority of public transit users either had very meager improvements in their employment accessibility (they could at most reach 10% more employment opportunities in 60 minutes, as seen from the light yellow colors), or their accessibility worsened (light and dark green effects). In fact, this is largely the case for people living in the southern periphery (the locality of Usme and parts of Ciudad Bolivar), where the implementation of the SITP actually negatively impacted their accessibility.

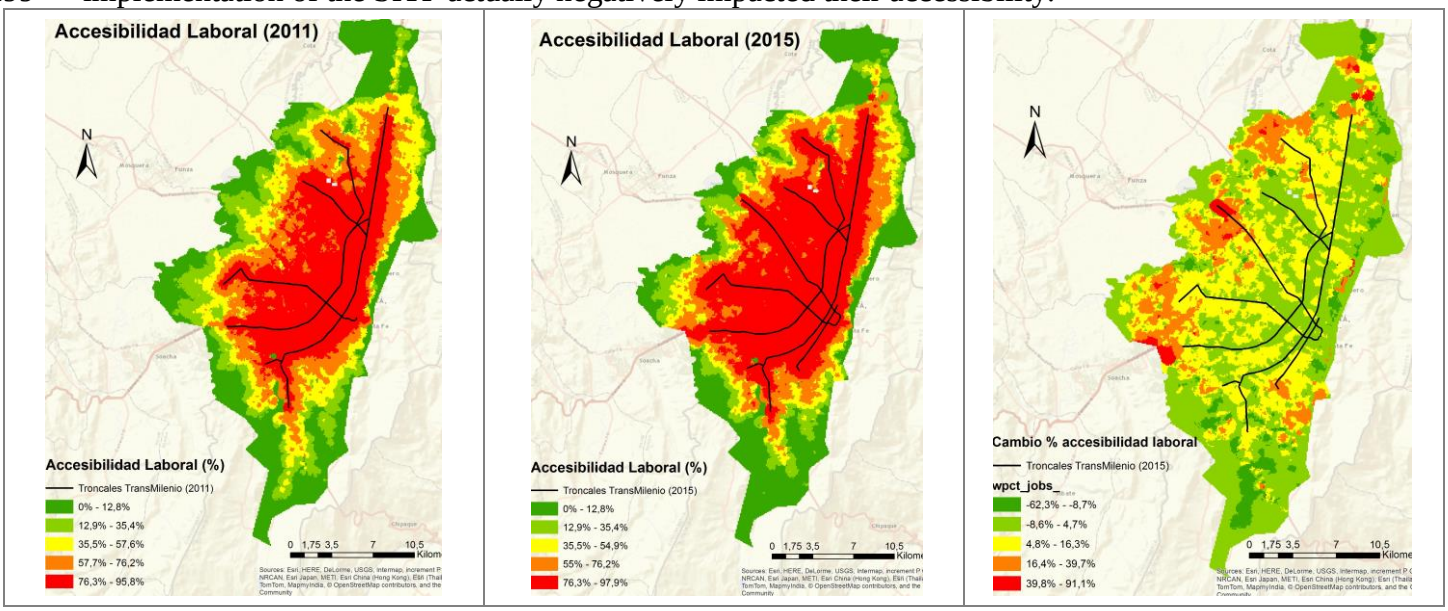

FIGURE 3 Employment accessibility using transit in Bogota before (left) and after (center) the SITP. Change on the right

Box: Accessibility in Soacha

Although Soacha is a municipality adjacent to Bogota, it functions as part of Bogota's greater metropolitan area. Soacha has a population of a bit more than 500,000 residents (density 14,900pp/km2), of which almost e commute daily to Bogota. For this reason, we performed a complementary analysis in Soacha in order to determine the change of accessibility generated by the implementation of a Transmilenio BRT corridor (corridor began operations in December 2013).

The results show significant improvements in terms of accessibility, mainly in the area that is adjacent to the Transmilenio BRT corridor. This area went from having an employment accessibility of 0-5% in 2011, to a 69% to 88% of accessibility in 2015.

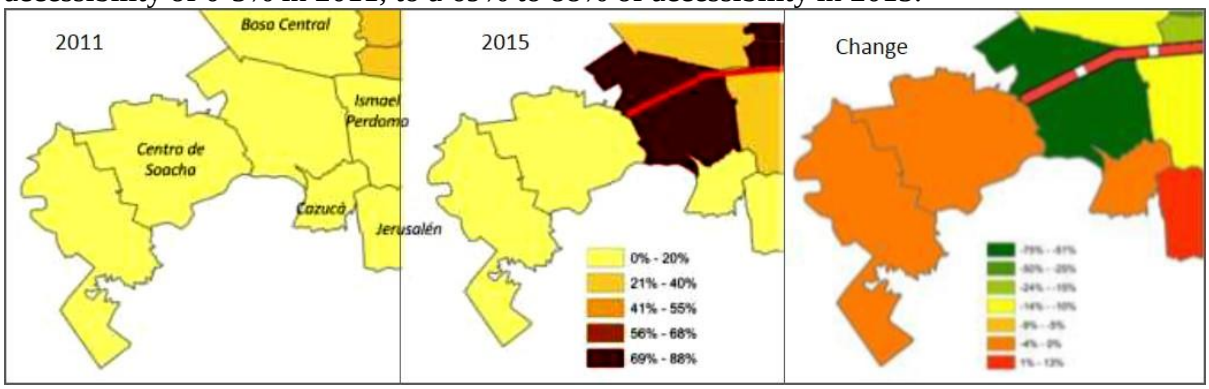

FIGURE 4 Accessibility Changes in Soacha

The improvements in accessibility for Soacha stem from the expansion of the Transmilenio BRT corridor. However, the overall accessibility could be improved if the Transmilenio system was integrated with the feeder routes and the local bus network. In addition, some studies indicate(16,17) that although accessibility has improved, many suffer from affordability constraints.

Although, the public transport system has coverage in almost the entire city, time is not the only constraints that people face when using Bogota's public transport system. Given that the cost of the transit system might also be a major barrier to accessing opportunities, we examined what was the effect in terms of accessibility if one also applies a budget or affordability constraint. This methodology to measure affordability builds upon the research of accessibility by applying a second tier threshold to the acceptable range of commutes. We calculated the number of employment opportunities that are accessible within a 60-minute travel time and a specified budget, COP1700 or COP2000, before and after the implementation of the integrated fare. This represents a 9-14% and 10-17% of income spent on transit for the monthly home-based work trip for the lowest income population, respectively.

This methodology yields the number of opportunities that are within a 60min travel time using public transport is the total potential accessibility, but only those locations that can be reached with the specified travel budget are considered to be accessible and affordable. Our research shows that under the current SITP fare structure, potential accessibility is reduced by as much as 54% when we add the budget constraint.

Comparing the two different systems using this affordability constraint shows that although accessibility in the city is high, this greatly decreases when we include the budget threshold. The results show that with a COP1700 budget (that covers the COP1550 traditional urban bus fare in 2015 or the SITP bus service with no transfer), accessibility in the city increases in the center of

the city, but decreases in the periphery, suggesting that some of the traditional urban buses provided slow but direct access to opportunities.

What is most interesting is the results from travel with a COP2000 budget. Given that, the current fare now allows you to use the SITP system and make one transfer, the overall accessibility in the city when compared to the traditional urban buses that required full fare for transfers. Since COP2000 will allow users to access the Transmilenio, the changes near the Transmilenio corridor are relatively small. The areas in the periphery of the city have the largest gain in terms of accessibility under the new fare structure. This is of particular importance as most of the lowest income population lives in these areas of the city and has the largest monetary constraint to use transit services.

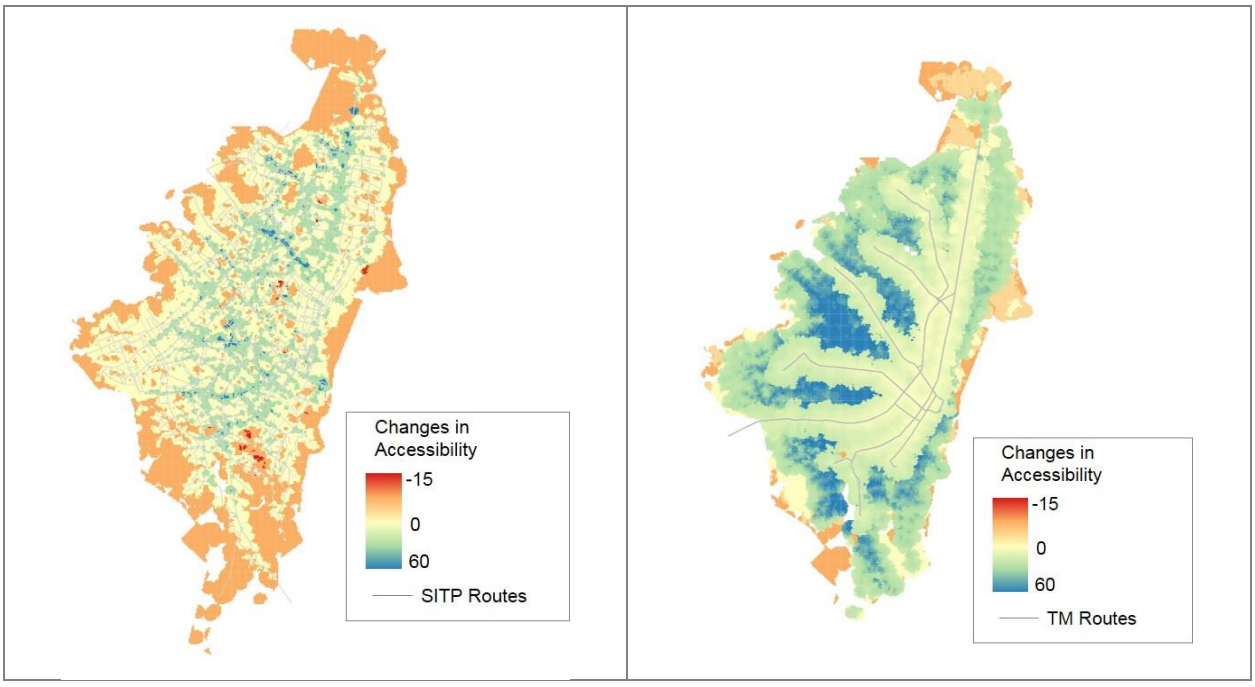

FIGURE 5. Changes in affordable employment accessibility, before and after the SITP, using 60min and COP1700 (right) and COP2000 (left).

From the previous analysis, the following issues are worth highlighting:

- The high concentration of jobs in specific parts of the city has caused major problems of unequal transit employment access that affects primarily the low-income population
- Transmilenio's high commercial speed (average commercial speed in 2015 was 32.5km/hr) and high frequency (5.1 min) are at the crux of the city's transit employment accessibility. The accessibility gains seen in the trunk corridors of the 26th Avenue, Suba and Soacha (Box above), exemplify these positive changes.
- In general, the SITP, which caters to 70% of Bogota's transit trips, has not significantly improved the employment accessibility of users; in some cases, such as in the southern periphery of the city, where many poor people live, accessibility has actually worsened.
- Adding a budget constraint reduces the overall employment accessibility, however the new integrated SITP fare increases the accessibility compared to the traditional urban buses, especially for population living in the city's periphery due to reduced transfer costs.

LESSONS LEARNT FROM BOGOTA'S BUS REFORM PROCESS

Bogotá has spurred a practice of innovation and excellence in the provision of public transport. In the aim to reduce, the negative externalities associated with transport and increase transit user benefits, numerous cities throughout the world have modeled their BRT systems after Transmilenio's experience. In Colombia, a national urban transport program was conceived based on Bogotá's public transport reform, with the aim to support the roll-out of BRTs in Colombia's largest cities. The success of Transmilenio also motivated the SITP; Transmilenio was able to prove that the process of reorganization and formalization of targeted high capacity corridors did indeed generate both user and societal benefits. For public transit users much of the benefits in Transmilenio came from travel time savings, as has been shown in our accessibility model; for society, research has proven that Transmilenio reduced the negative externalities associated with Bogota's traditional urban buses.

Yet, Bogotá's implementation of the SITP and to a similar extent Colombia's experience with the implementation of BRTs in its secondary cities is not generating the expected win-win situations. Many of the elements of the reform process aimed at reducing externalities are effective— bus scrapping, fleet renewal, formal employment for drivers and maintenance personnel— but there has been little attention to focus public transit reform around the user's perspective. Although Transmilenio's value proposition for the user was very clear— better speed and lower travel times— the value proposition for the user in the SITP is not obvious. By design, the system is adding a lot of perceived discomforts for the user: no cash handling (smart card only), longer waiting times at bus stops, longer routes and no bus hailing or un-boarding at their discretion. In fact, the conceptual design of the SITP contemplates no change in the generalized cost of travel compared to the traditional urban buses (80 min). Furthermore, although the SITP envisions an integrated fare and was structured to maintain the user fare at the level of the traditional urban buses when it was launched, it did not account for the fact that users could 'negotiate' discounts with bus drivers in the traditional system(18). In the case of BRTs in other Colombian cities– the increases in speed were achieved – but the demand levels have not been substantial enough to generate a financially feasible system that would pay for the costs of formalization. Overall, this largely explains the lack of enthusiasm about the bus reform process from users and the political discomfort in cities of the developing world with embarking on this process.

In reality, reaching both objectives—societal benefits and gains for public transit users— is extremely complex. Formalization brings forth society benefits –better safety, reduction in pollution and congestion- but it is an expensive process that reduces user comfort. As this analysis has demonstrated, it is hard to generate tangible user benefits without travel time gains, and even so, there needs to be enough demand so that the magnitude of the user benefits is enough to pay for the formalization costs. Another possible option is for these costs to be paid by all rather than only by transit users, as is today the case in the Bogotá and Colombian where many costs of formalization are paid for by the user fare, which is set close to cost recovery. In other words, that these costs of formalization are paid for through the tax base, in the form of a general subsidy, similar to European and US cities. But the experience in the United States suggests that if the political will is not strong, or if fiscal space is an issue, which is almost always true in the developing world, then subsidy based financing will almost invariably result in a loss of quality and perhaps labor capture (which is the experience of the United States, Argentina, Brazil)(19).

Another option is to focus the reorganization only in the high capacity corridors and not impose a system-wide formalization. The challenge is then, how to capture non-user benefits such

as increased safety, lower pollution and congestion. Until recently there did not seem to be any options – cities either have had poor quality informal systems with the negative externalities or they struggled with the costs of formalization (Bogota's SITP, Santiago de Chile's Transantiago, the integrated public transit system in Curitiba).

A POSSIBLE WAY FORWARD: INCREAMENTAL, FLEXIBLE & TECHNOLOGY- ENABLED REFORM

As a new administration took office in Bogota in January 2016, they have pledged to expand the Transmilenio BRT network as one of the critical strategies to improve the city's mobility. In line with this, the administration has also indicated that it will reinforce the SITP as a trunk-feeder system, to generate greater travel-time savings. This strategy might improve the SITP's accessibility, but it also runs the risk of adding further "discomforts" to users by increasing transfers. Another strategy that has been discussed by the administration is to employ more broadly "dual door" bus fleet that can either run services in segregated BRT lanes, and thus generate the speed and time saving users value, but are also able to run in mixed traffic to avoid the transfers that users despise.

But perhaps technology offers another path for analyzing the performance of public transport systems and future incremental reform. A technology-enabled revolution can reduce the negative externalities of informal services without losing what makes them financially feasible: an agility and responsiveness for demand that government planned systems do not have, while combining labor regime that reflects the real market. In informal services, much like Bogota's penny war, the lack of information about demand and fighting for passengers leads to safety problems and oversupply. Can smart phones change that? Can we improve the operating environment for operators– and make incentives to make their behavior compatible with safer, less polluting, less congested cities?

Informal transit "efficiency" hinges on basic information-related market assumptions of perfect competition and perfect consumer information, clearly elusive in practice. Externalities and collusion necessitate regulations, but, in an atomized stasis, government lacks the capacity and/or motivations. Information plays an important role here as well; information being power, informal operators and associations have strong incentives to conceal information to tip the balance of power in their favor vis-à-vis regulators and competitors. Recent ICT-related advances, however, seem poised to change this "hidden information" landscape: relatively easy-to-use, standardized formats for codifying public transport information and increasing availability of affordable detailed spatiotemporal sensing, communication, and computing power(*20*).

In this paper, we start to uncover the potential of this technology revolution for local transport planning. The use of machine learning and high-resolution imagery provides a useful lens with which to explore at detail the spatial composition of a city. These tools allow us to examine the spatial patterns of a city and make better spatial data-driven solutions for local problems. As was explored here, the increase in computing power, high-resolution data and open source tools allows us to quickly calculate accessibility and affordability patterns at high resolution. These understanding of accessibility lets us study the local impacts of different transit systems.

Into this environment comes a range of new capabilities associated that can be leveraged to improve data collection, monitoring and operations of the public transport sector.

Sensors and crowdsourcing are changing the ways to incentivize feedback from public transport users and better behavior from drivers. For instance, smartphones' accelerometers can

be used to record driver behavior, while free Wi-Fi in the buses, gives consumers an incentive to rate drivers. This system is currently being piloted in Nairobi. The data can be used to coordinate with insurance providers and reward good driving habits. The city can use this data to identifying the worst drivers, operators and vehicle performance; and perhaps following up on regulating those. Similarly, after identifying the best performers, the city may use the information to provide privileges to the best operators; such as access to priority lanes or the possibility of offering premium services with premium prices.

Research from the International Transport Forum (ITF) suggests that shared mobility will radically change public transport and most traditional bus services will disappear (21). Technology provides the tools with which to transform traditional services into complementary shared mobility. Shared mobility provides a platform to increase quality, lower cost and externalities in midsized cities in the developed world, where labor costs are high and demand is relatively low. While the economics in cities of the developing world are different (labor costs are much lower and demand on key corridors are much higher), these findings could still be relevant. Can we find ways for incremental reform of informal public services that also uses the demand discovery element of crowdsourcing platforms, such as Uber, to incentivize a better service?

The reform process in Bogota launched a mini-revolution in the bus business that brought forth experimentation with business models, formalization of atomized paratransit, and priority access. The findings from our research suggest that there is a need for a new revolution –-one that possibly looks at more flexible, incremental and technology-enabled user benefits and at the same time delivers to reduce negative externalities.

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