BRT Reforms in Colombia: an ex-post evaluation

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Abstract

We use monthly data on transit supply and ridership to evaluate the impact of BRT type reforms in intermediate cities in Colombia. We find that these reforms are associated with a decrease in aggregate transit ridership. This is particularly troubling, since it points to a reduction in the attractiveness of public transport for users and a substitution to other potentially more unsustainable modes, such as private vehicles or informal taxi services. We also show that reform reduced fleet size and commercial kilometers supplied and we conjecture that this, together with additional transfers required in the new systems, raised the generalized cost of transport for transit services. We present circumstantial evidence that this conjecture is correct and argue that this was probably the case in other Latin American experiences, such as Panama City, Santiago and Lima.

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1 Introduction

Colombia was a pioneer in transit reform. Although Curitiba in Brazil had developed a BRT system since the 1970's – and was an inspiration for Colombia's reforms– it was the success of the Transmilenio system launched in Bogota in December 2000 that received regional and worldwide attention.[1]

Phase 1 of Transmilenio consisted of a BRT with 42.3 kilometers of exclusive bus infrastructure, boarding stations, electronic prepayment system, high-capacity articulated buses as well as feeder services (in mixed traffic) integrated with the trunk services operating in the corridors. This initial phase had a positive impact on travel times and ridership, as well as lowering safety and environmental externalities (Echeverry, et. al, 2004; EMBARQ, 2017). It was followed by two more stages, expanding the exclusive corridors by 48.9 kilometers between 2002 and 2006 (Phase II) and by an additional 21.7 kilometers between 2012 and 2016.[2]

The operational and political success of Transmilenio –and Curitiba earlier– ushered an era of transit reforms in Latin America as well as the rest of the world. Transmilenio generated an optimism among policymakers in developing countries that it was possible to increase quality of life and mobility for urban citizens without the massive operational transit subsidies characteristic of developed countries. Reforms were soon implemented in Mexico City, Monterrey, Acapulco as well as other cities in Mexico, Quito and Guayaquil in Ecuador, Lima (Peru), Ankara (Turkey), many cities in China and Brazil as well as indirectly inspiring city-wide non-BRT reforms in Panama City and Santiago (Chile). According to Global BRT Data, an organization that collects information on BRT bus systems, over 33 million people use a BRT type system around the world on a daily basis, 61% of them (over 20 million

[1] According to Fedesarrollo (2013), Transmilenio was presented as the "world reference point for BRTs" in the Fourth International Massive Transport Forum, Bogota, 2009. By BRT we mean any transit system that includes priority infrastructure for buses. These can be 'light' (just bus priority infrastructure) or 'full' (including off-board payment stations, formalization of firms and drivers, fleet renovation, fleet management systems and electronic payment technology) or any combination in between.

[2] These numbers are taken form Transmilenio (2016). This paper is not intended as a description or evaluation of Transmilenio so the presentation here is brief and no mention is made of current challenges.

people from 55 cities) in Latin America alone.[3] Even in the United States there is a growing interest in these systems with 13 cities already having some type of bus priority infrastructure.

In Colombia, the success of the reform in its capital Bogota spurred a series of reforms in intermediate cities. These reforms, called SITM (Integrated Massive Transport Systems for its acronym in Spanish) were part of a new National Policy on Urban Transport (PNTU) launched in 2002 that aimed at replicating the success of Transmilenio in the main regional capitals.

Despite the scale of reforms in Latin America and the world during the last 20 years and their importance for mobility for millions of people daily, there is scant research on their impact on ridership, commuting time and mobility in general. Notable exceptions include Echeverry, et. al (2004) for Phase I of Transmilenio, and EMBARQ (2017) for Transmilenio, Metrobus in Mexico City and Rea Vaya in Johannesburg. However, these studies undertake a Cost-Benefit Analysis of each reform. They do not evaluate their impact taking into account a suitable control group.[4]

An evaluation of the primary goals of any transit reform, namely to promote the use of public transport and improve the quality of service to passengers, has not been undertaken. This omission in the literature is troubling given that many reforms in Latin America have faced or are facing severe difficulties and have not been well received by the general public. In Panama City for example, the financial and operational problems faced by the new system ended with the State taking over the private concession and operation in 2015, just two years after it was fully implemented.[5] Transantiago in Santiago, Chile, is a byword for “the worst public policy implemented” in the last 20 years in the country after its troubled implementation in 2007 (Gómez-Lobo (2012), Gallego, Montero y Salas (2013)).[6] The experience in Lima and several cities in Mexico is also complex. Even in Colombia, a

[3]http://brtdata.org, last accessed March 11, 2019.

[4]They also evaluate environmental and traffic benefits. In the case of Santiago, see Figueroa, et. al (2013) for the impact of Transantiago on air pollution.

[5]See http://www.mibus.com.pa/nosotros/historia/. Last accessed March 11, 2019.

[6]The quote is from the ex Minister of Transport (2007-2010), Rene Cortazar. The crisis associated with this reform had important political implications (Mardones, 2008) and it even has its own Wikipedia entry (‘Crisis del Transantiago’).

city-wide non-BRT reform in Bogota to formalize transit services outside the Transmilenio network, called SITP, has encountered important financial and operational problems since its inception in 2014. In the case of the SITM reforms in intermediate cities, we document below they are also facing financial and operational difficulties not envisaged when they were designed, putting pressure on the municipal governments of these cities that now have to fund increasing operational deficits.

Why have reforms after Transmilenio not replicated its success? Rather, the experience in Latin America and in Colombia in particular seems to be rather negative (with a few exceptions that will be discussed in the conclusions) with lower than expected ridership levels and circumstantial evidence that point to worsening transit experience for users. An important obstacle to answering these questions is the lack of suitable data to evaluate the reforms in most countries. Although passenger, operational and ridership data is available for the new BRT systems, there is no comparable data for the pre-reform period –characterized by informal services without electronic payment systems— or for the traditional (and informal) services that still operate along with the modern BRT systems. The exception is Colombia where a unique dataset, Encuesta Urbana de Transporte de Pasajeros (EUTP), is available with monthly information on transit demand levels, fleet in operation, fleet characteristics (bus types) and commercial kilometers operated for 57 municipalities since 2005. This information covers the traditional public transport services as well as the SITM services.

In this paper we use the EUTP data to evaluate the impact of SITM reforms in Colombia on transit supply and ridership. Since not all cities implemented a reform nor, in the cities that did, at the same time, we are able to use a difference in difference estimator from the policy evaluation econometric literature to estimate the impact of SITM reform.[7] This allows us to define a control group of cities to contrast with those that implemented a SITM and thus identify the effects of these reforms controlling for general macroeconomic and other confounding factors (rising motorization rates, for example). We find that SITM reforms are associated with an important decrease in fleet size and commercial kilometers supplied. In turn, we find that citywide ridership levels (SITM plus conventional services) fell after a

[7]See Imbens and Woolridge (2009) for a review of this literature.

reform. This is particularly troubling, since it points to a decrease in the attractiveness of the public transport system for users and a substitution to other, potentially more unsustainable, modes such as private vehicles or informal taxi services.

We rationalize these results with the following conjecture. The SITM reforms were expensive, in the sense that they increased capital and operational costs by formalizing drivers, fleet renovation and new technology (electronic prepayment systems, fleet management technology) as well as the need to fund the regulatory agency and a share of the infrastructure investments. Since no operational subsidies were considered, the additional costs had to be funded from fare revenues and probably indirectly led to an excessive fleet reduction and rationalization of routes (feeder-trunk design) in order for costs and revenues to match. In turn, this would have increased access and waiting times and lowered passenger comfort aboard buses. Unlike Transmilenio in Bogota, the exclusive bus infrastructure in intermediate cities are relatively short and thus lower in-vehicle travel times in trunk services most probably did not compensated for the higher access and waiting times, with the ensuing reduction of demand compared to projected levels. We present circumstantial evidence that this conjecture is plausible and argue that this was probably the case in other Latin American experiences, such as Santiago and Lima.

To the best of our knowledge, this paper is the first attempt to evaluate the reforms in intermediate cities in Colombia using rigorous econometric techniques. The results have important implications for policy design in the transport sector in Colombia and calls for a review of the PNTU almost 17 years after its initial launch. But the results also have important implications for regional reforms, most of which have been inspired by the Colombian experience. Given the rather critical evolution of many transit reforms in Latin America, its time to rethink policy in this area.

The paper is organized as follows. In the next section we review the Colombian transport policies as formalized in the PNTU and the implementation of BRT reforms (called SITM) in six intermediate cities. We then present the data used in this study. The main section of this paper then presents the econometric methodology, estimated results, and a discussion of our findings including a hypothesis rationalizing these results. We also present circumstantial evidence for our hypothesis and argue that it may also explains some other problematic reforms in Latin America. The paper concludes with a section summarizing the results and discussing the policy implications for Colombia and the region as a whole.

2 SITM in Colombia

As discussed above, the successful launch of the first phase of Transmilenio in 2000 was a catalyst for transit reform in the region and the world. In Colombia, policymakers developed a National Urban Transport Policy (PNTU) in an attempt to replicate the success of Bogota in other intermediate cities in the country.

This policy was formalized through several laws, regulations and programs, starting with the document CONPES (2002).[8] This document first presents a diagnosis of the state of transit services in the different Colombian cities. It criticizes traditional transit services due to the informality of operators and labor relations, the over supply of routes and buses, the average age of the fleet, and as a source of important environmental and traffic safety externalities.

CONPES (2002) also delineates the general elements of the new PNTU and established that cities with more than 600,000 inhabitants would be subject to infrastructure investments in exclusive corridors for high-capacity buses in the context of an Integrated Massive Transport System (SITM) BRT type reform.[9]

CONPES (2003) complements the earlier document and provides further guidelines of the PNTU policy. This policy called for fare and operational in-

[8]CONPES is the acronym for the National Commission for Social and Economic Policy. It is the highest authority in the government for economic and social development. This Presidential advisory board is presided by the Vice-President and members include all Ministers along with the directors of several government agencies. See https://www.dnp.gov.co/CONPES/Paginas/conpes.aspx for more information.

[9]For cities with less than 600,000 inhabitants, the policy called for a Strategic Public Transport System (SETP) reform that does not include BRT type infrastructure. During the time span of our data no city had implemented a SETP and this paper does not address these types of reforms.

tegration of services, elimination of over-supply of buses (scrapping program for old buses), formal operators and labor relations, and new institutions in each city to plan, implement and manage the new systems called *Entes Gestores*. Furthermore, the PNTU established that an SITM should operate with electronic prepayment cards, off-board payment stations, centralized system of fare collection, modern fleet management technology, a renovated fleet and a redesign or 'rationalization' of the route network.

In terms of our definition of a BRT contained in footnote 1, the PNTU envisaged top-of-the-line 'full' BRT systems for the SITM reforms.

On the funding side, the PNTU established that fare revenues should cover the purchase, operation and maintenance of the new fleet, fare collection system, the *Ente Gestor* (system manager and regulator), infrastructure conservation, fleet scrapping program, and the investments in depots, garages and inter-modal stations. The national government would co-fund the infrastructure investments (dedicated bus corridors) as well as providing technical assistance to local governments in the design and implementation of the reforms.[10]

It is important to note that the PNTU did not consider operational subsidies as part of the reform process. A fraction of the infrastructure investment, as well as the total operational and management costs, fleet scrapping and renovation, fleet management and fare collection equipment and the institutional budget (*Ente Gestor*) were to be funded exclusively from fare revenues. Given the political difficulty in raising transit fares, the implicit assumption made was that the elimination of inefficiencies of the traditional systems (over-supply of services and redundant network route design) would fund the additional costs of the SITM. This assumption was very much influenced by the experience of the first phase of Transmilenio, where operating subsidies were not required. As will be discussed below, it was the wrong assumption to make in the case of intermediate cities.

Starting in 2006 several SITM began operation in the main regional capitals of Colombia: Pereira (2006), Cali (2009), Bucaramanga (2010), Bar-

[10] Another CONPES document established the conditions for the co-financing of the investment plans.

ranquilla (2011), Medellin (2011) and Cartagena (2016). In each of these cities, BRT systems were introduced by restructuring the route network into a feeder-trunk configuration, with trunk services operating in exclusive corridors, and the fleet was rationalized by scrapping part of the old fleet and thus reducing the 'over-supply' that characterized the conventional systems.[11] Table 1 presents some of the main characteristics of the new SITM systems.

These reforms have modernized the transit sector in these cities, formalizing labor relations for drivers and other workers, the creation of real operating companies instead of informal organizations affiliating routes and reduced negative environmental and traffic externalities (Fedesarrollo, 2013). However, these reforms have also faced many problems. Chief among these is the fact that demand estimates at the time of the financial structuring of the reforms have not materialized.

Table 2 presents the data of the ex-ante estimated demand levels in the SITM systems and the real observed demand in March 2015 for five cities and 2017 for Cartagena. It can be seen that real demand has been much lower than projected. In some cities, demand levels were a third of those projected prior to the reforms.

[11] In spite of this 'rationalization', some traditional services remained in operation in each city, sometimes competing directly with the new SITM services.

Table 1: Description of SITM in Colombia

	Barranquilla (Transmetro)	Bucaramanga (Metrolinea)	Cali (MIO)	Cartagena (Transcaribe)	Medellin (Metroplus)	Pereira (Megabus)
Inauguration date	July 2010	Dec. 2009	May 2009	March 2016	Dec. 2011	Aug. 2006
BRT kms	14	17.6 (2018)	36.07	10.7	18.0	15.5
Pop. (millions):						
City	1.23 (2018)	0.53 (2018)	2.45 (2018)	1.04 (2018)	2.53 (2018)	0.48
Met.Area	1.90 (2010)	1.09 (2011)	3.52 (2014)	1.32 (2015)	3.44	700.58
Density (Met. Area)	3,650 (2008)	740	327 (2014)	382.4 (2015)	5,840	828.1 (2015)
Pax/year (millions)	34.5	21.6 (2012)	141.4	12.0	18.0	36.4 (2017)
Fleet:						
High-capacity	39	29	199	18	20	49
Total	-	131	722	54 (2016)	67	-
Speed (kms/hr)	22	20 (2012)	17.8 (2014)	-	16	20

Source: BRTdata.org. Last accessed May 6th, 2019.

Table 2: Ex-ante projections and effective demand for SITM (pax/day)

	Barranquilla	Bucaramanga	Cali	Cartagena	Medellin	Pereira
Projected	305,000	387,500	960,000	452,000	176,500	140,000
Real	102,463	137,585	468,398	90,682	133,557	90,288
Real/projected	33.6%	35.5%	48.8%	22%	75.7%	64.5%

Source: DNP (2016) except for Cartagena. This information is as of March 2015 for these cities and is consistent with that reported by Fedesarrollo (2013) a few years earlier. The information from Cartagena is for 2017 and comes from Cartagena cómovamos (2017). In this last city, projected demand is for 2020 when all routes are in operation while effective demand is for 2017. The system currently operates with 170 buses. There are 329 additional buses expected to enter operation by 2020. Even under an optimistic assumption that the additional services carry the same demand per bus as those already in operation, total demand would be 175.5 thousand passengers per day, less than 40% of expected demand.

Low demand levels for the new BRT systems are problematic for several reasons. First, it runs counter to the objective of promoting the use of public transport. Second, lower than expected demand has impacted fare revenues, generating important financial deficits for these systems that were not expected at the design stage. Since the PNTU did not contemplate operational subsidies from the national government, these deficits have been funded from municipalities, straining local government budgets. In turn, to lower these deficits, some *Ente Gestores* have lowered supply levels (frequency and routes) in an effort to reduce operational costs. However, these developments risk generating a downward spiral of lower quality of service that in turn lowers demand and income even further (Fedesarrollo, 2013).

Today, all SITM reforms have demand short-falls that affect their financial and operational sustainability.[12] The rest of this paper will analyze what happened with these reforms and why demand shortfall may have come about.

3 Data

The data used comes from the 'Encuesta Urbana de Transporte de Pasajeros' (EUTP) of the national statistical office DANE. This database contains monthly information on the number of passengers, commercial kilometers, number of vehicles in service, and type of vehicle for the main urban zones of Colombia.

The original data-set contains information from 57 municipalities. However, 23 of these –most from the Department of Cudinamarca– did not have information for years 2005 and 2006. In the case of the municipality of Envigado, information is only available from 2011 and for the case of Rioacha, no information is available for the last four months. Both were dropped from

[12]It is common to find in the Colombian press reports regarding the critical situation of the SITM systems. See for example:
http://www.eldiario.com.co/seccion/LOCAL/transportes-masivos-problemas-intensos1804.html;
http://www.vanguardia.com/area-metropolitana/floridablanca/431239-metrolinea-se-convirtio-en-un-muerto-andante-alcalde.
http://www.eluniversal.com.co/cartagena/alcaldia-solicito-20-mil-millones-para-garantizar-la-operacion-de-transcaribe-285620-EUEU402475.

the database. Municipalities belonging to a metropolitan area were aggregated. The result was a database comprised of 24 cities or metropolitan area with information from January 2005 until March 2018 (excluding the 23 municipalities from the Department of Cudinamarca without information until 2007) or from January 2007 to March 2018 for the 24 cities including the 23 municipalities from Cudinamarca.

Table 3 presents descriptive statistics for each urban area. It must be borne in mind that these figures are for all transit services, traditional and SITM in those cities that implemented a reform.

4 Model and results

In order to analyze the impacts of the SITM in the use of public transport, other confounding effects must be controlled for. During the period of reforms, general economic growth most probably had an impact on motorization rates, particularly of motorcycles. In the last two decades there has been an exponential growth in motorcycle ownership, fuelled by trade agreements that have lowered the price of imported vehicles as well as general economic growth.[13] The motorcycle boom also generated an informal motorcycle taxi service industry that competes directly with mass transit services.

In order to control for these and other confounding factors we exploit the fact that not every city implemented an SITM, or when they did, not at the same time. Thus, we can use cities without a SITM at a certain period as a control group to examine the impact of reform on cities that did implement them. For this to identify correctly the impact of reform we must assume that other confounding factors have the same effect on cities with and without a SITM, also called the 'common trend' assumption in the policy evaluation literature. We will come back to this issue further below.

[13] According to information from the Colombian statistical office (DANE), the number of vehicles in Colombia grew from 3.9 million in 2005 to 10.1 million in 2013, increasing the motorization rate from 0.09 vehicles per person in 2005 to 0.22 in 2013. On the other hand, in 2002 motorcycles represented 32.7% of vehicles while in 2016 they represented 56.2% (ANDI, 2017).

Table 3: Descriptive statistics by city or metropolitan area, average 2007-2017

	Passengers (monthly)	Vehicles in service (average per day)	Kilometers operated (month)
Armenia	1,689,443	323	1,811,417
Barranquilla	25,821,596	3,236	16,263,049
Bogotá D.C.	146,355,431	14,044	76,927,510
Bucaramanga	10,366,237	1,485	10,707,109
Cali	22,779,925	2,483	16,247,893
Cartagena	11,716,746	1,403	6,176,049
Cúcuta	7,940,334	1,644	9,347,742
Cundinamarca	10,546,852	1,788	10,951,516
Florencia	442,547	90	372,794
Ibagué	6,242,525	1,021	6,065,796
Manizales	5,932,998	789	4,173,700
Medellín	36,452,768	4,641	19,537,543
Montería	1,084,321	147	896,364
Neiva	2,439,814	535	3,639,843
Pasto	3,077,436	480	1,901,913
Pereira	7,296,376	717	4,528,464
Popayán	2,992,759	563	4,028,302
Quibdó	583,597	105	417,435
Riohacha	128,905	22	126,495
Santa Marta	9,995,147	745	4,001,694
Sincelejo	592,445	105	417,435
Tunja	1,968,675	450	2,363,547
Valledupar	818,514	161	971,424
Villavicencio	4,945,866	947	4,745,249

Source: EUTP, Dane. The average daily number of buses in operation and the number of kilometers operated is the simple sum for all different type of vehicles. The above figures exclude passengers, vehicles and kilometers of light rail, metro, and cable-car services.

4.1 Model

The general model estimated is:

$$ln(y_{it}) = \alpha_i + \gamma_t + \beta \cdot SITM_{it} + \epsilon_{it} \quad (1)$$

where y_{it} is the dependent or outcome variable (either number of passengers, number of vehicles in operation or commercial kilometers), i denotes the city and t the month, α_i is city fixed effect to control for factors that are specific to each city (size, density, climate, for example), γ_t is a time fixed effect to control for shocks that are common to all cities (general economic conditions, for example), and $SITM_{it}$ is our main variable of interest. This variable is defined as the number of trunk SITM vehicles as a proportion of all public transport vehicles (SITM plus conventional) in the city. This variable takes into account the growth of the SITM through time and is relevant when a SITM has been introduced in phases as was the case in most cities.[14]

It would have been ideal to control for other variables that may affect transit demand; for example, fares. However this information was not available for each city month.

The model was also estimated using different samples. Some estimations are for the entire period January 2005 to March 2018 excluding the municipalities from the Department of Cudinamarca that did not have information for 2005 and 2006. Other estimations where undertaken with the sample from January 2007 to March 2018, but in this case we cannot estimate the impact of the SITM in Pereira that began operation in August 2006.

In both samples, the model is estimated for all cities and also for a subsample of the largest cities, which in this case are those urban areas that on average in 2007 had more than five million transit passengers per month. Restricting the sample makes cities more homogeneous at least in size and may be important if we are not controlling sufficiently for confounding factors that may differ among cities.

[14] The $SITMv$ variable is bounded between 0 and 1, and represents the relative importance of the trunk SITM services in relation to the total public transport system, at least as far as fleet is concerned. Estimations using a discrete variable indicating whether a SITM was in operation or not gave similar results as those reported below but parameters had lower significance levels in some estimations.

During the 2005-2018 period, Bogota always had a BRT in operation (Transmilenio) and so it is excluded from the estimations.[15] Pereira is also excluded when the sample is restricted to 2007-2018. Since in this city the SITM began operation in August 2006 there is scant information for the period before this reform. Therefore, we also test results excluding Pereira from the sample in some estimations even when we use the 2005-2018 data.

The case of Medellin is also complex. The SITM in this city is relatively small within an integrated system that includes a Metro, light-rail and cable-cars. These other transport infrastructures have been growing during the period and may have an impact on transport demand that is independent of the introduction of the SITM. In addition, in this city the bulk of bus passengers use the conventional non-integrated services operated by some 5,000 buses. In comparison, the SITM trunk services in this city represents less than 1% of the total fleet. Therefore, we also exclude this city in some estimations in order to test the sensitivity of results.

4.2 Results for total transit passengers

Tables 4 and 5 show the results for total passengers using public transport (both SITM and conventional). Table 4 restricts the sample to the 2007-2018 period and includes the information of those municipalities without information for the years 2005 and 2006. As discussed above with this sample we have to exclude Pereira (as well as Bogota). Table 5 includes the whole sample but eliminating the data for the municipalities of Cudinamarca without information for the first two years.

The results of Table 4 indicate that the variable SITM has a negative impact on the total number of transit passengers (SITM plus conventional). At the mean value of the SITM variable, the coefficients imply a reduction in demand between 9% and 13% depending on whether Medellin is included or excluded from the sample.

[15] In addition, the characteristics of this city, being the largest in Colombia and where trip length are probably longer, together with a much longer exclusive bus corridors, imply that the effects of a BRT may be quite different from those in smaller cities.

Table 4: Estimation results for the logarithm of total transit passengers, January 2007-March 2018

	excluding Bogota and Pereira		excluding Bogota, Pereira and Medellin	
	(1)	(2)	(3)	(4)
	All cities	Large cities	All cities	Large cities
SITM	-2.960*	-3.118**	-2.935*	-2.979**
	(1.286)	(0.808)	(1.317)	(0.878)
Obs.	2,834	1,485	2,699	1,350
r^2	0.127	0.545	0.129	0.581
Δpax	-9.3%	-9.8%	-12.5%	-12.7%

Notes: Robust (Huber-White) standard errors in parenthesis. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. This estimation excludes the municipalities of Envigado and Rioacha. Large cities are those with at least five million passengers per month on average in 2007. All models include city fixed effects and monthly time effects. Δpax is the impact of reform on the number of passengers at the average value of the variable SITM in the sample.

When we use the 2005 to 2018 sample (Table 5) the results are similar to those of the previous table. All estimated parameters have a negative sign, although not all of them are statistically significant. The estimated coefficients imply a drop in demand between 6% and 9%.

All the coefficients shown in Tables 4 and 5 are negative. Thus, there does not seem to be any evidence that a SITM boosted transit use in the cities that introduced such reforms. On the contrary, the evidence seems to point in the other direction: that a SITM reduced the use of public transport and by a significant amount.

Before asserting this last conclusion we must assure that the results are not dew to other factors. It may be that in that public transport demand was falling faster in those cities that introduced a SITM compared to the others. In Appendix A we explore this issue by testing the common trend assumption using placebo regressions. It is shown that there is no evidence to reject the null hypothesis of a common trend.

Table 5: Estimation results for the logarithm of total transit passengers, January 2005-March 2018

	excluding Bogota		excluding Bogota and Pereira		excluding Bogota, Pereira and Medellin	
	(1)	(2)	(3)	(4)	(5)	(6)
	All cities	Large cities	All cities	Large cities	All cities	Large cities
SITM	-1.571	-2.261**	-1.509	-2.119*	-1.857+	-2.241*
	(0.967)	(0.629)	(0.985)	(0.671)	(1.034)	(0.801)
Obs.	3,338	1,749	3,179	1,590	3,020	1,431
r^2	0.202	0.634	0.208	0.672	0.206	0.658
Δpax	6.4%	9.2%	7.0%	9.8%	8.0%	9.6%

Notes: Robust (Huber-White) standard errors in parenthesis. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. This estimation excludes the municipalities of Envigado and Rioacha. Large cities are those with at least five million passengers per month on average in 2007. All models include city fixed effects and monthly time effects. Δpax is the impact of reform on the number of passengers at the average value of the variable SITM in the sample.

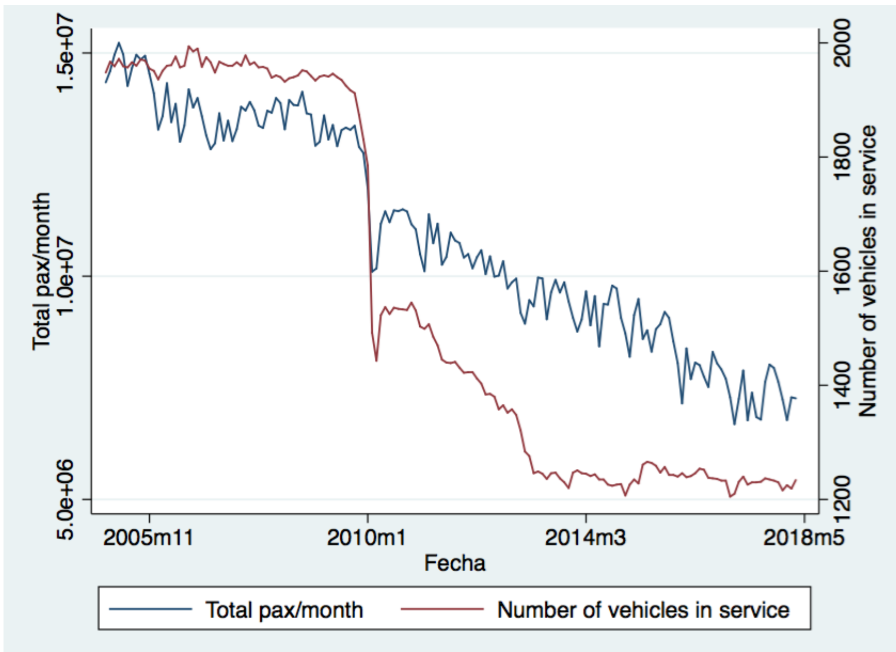
A graphical analysis for some cities clearly shows an effect of SITM reform on transit demand that probably cannot be explained by other factors. The clearest case is Bucarmanga shown in Figure 1. It can be seen that the total number of passengers dropped from around 14 million to close to 10 million around the date that its SITM began operation in early 2010. It also coincides with a sharp drop in the total number of vehicles (both SITM and conventional) in service around the time of reform. This last observation gives some clue as to the possible explanation for the drop in transit demand which is explored next.

4.3 Discussion and additional results

The above results indicate that SITM reforms are associated with a drop in total public transport use and we also presented evidence that demand levels for SITM services in particular were much lower than originally projected.

What can explain this phenomena? In order to develop a hypothesis we first need to discuss the determinants of the demand for transit.As is well

Figure 1: Total passengers per month and number of daily vehicles in operation, Bucaramanga 2005-2018



Source: EUTP, DANE.

know, this will depend on fares, access, waiting and in-vehicle time, as well as other factors such as congestion levels in buses, quality of the vehicles among others. All these variables are readily summarized in the generalized cost of travel (GCT).

Recent research in North America indicates that frequency of service is one of the main factors that determines transit demand (Boisjoly, et. al, 2018).[16] Frequency will affect waiting times, a key component of the generalized cost of travel. In turn, frequency is determined by the fleet size in operation.

[16]See also the review of the earlier literature by Currie and Wallis (2008) who conclude that to increase ridership it is necessary to increase coverage, frequency and the general supply of transit services.

To see the importance of waiting times for travel demand, Table 6 presents an illustration using current data for Colombian intermediate cities that implemented a SITM. The table shows the value of extra waiting times as a fraction of fares for each city in April 2019.[17] A one minute increase in waiting times is equivalent to a 5%-7% increase in fares. If waiting times increase by 5 minutes this is equivalent to a 30% increase in fares and double this amount for an extra 10 minute wait. Therefore, extra waiting time implies a significant increase in the GTC of transit services. Access time is also costly, roughly similar to waiting time costs (Small and Verhoef, 2007).

Table 6: Waiting time cost as proportion of fares, SITM cities, April 2019

City	Fare (USD/trip)	Additional minutes of Waiting time		
		1	5	10
Barranquilla (Transmetro)	0.69	6.3%	31.5%	63.0%
Bucaramanga (Metrolínea)	0.77	5.7%	28.3%	56.6%
Cali (MIO)	0.63	6.9%	34.7%	69.3%
Cartagena (Transcaribe)	0.78	5.5%	27.7%	55.5%
Medellin (Metroplus)	0.68	6.3%	31.7%	63.3%
Pereira (Megabus)	0.66	6.6%	33.0%	66.0%

Sources: The value of travel time is assumed to be 1.3 USD per hour. Fares for each city were obtained from the respective web pages on the 25th of April 2019 and the exchange rate for the same day (3.200 Colombian pesos per USD), and a factor of 2 of the value of waiting time over value of time.

What impact could the SITM reforms have had on the generalized cost of travel on public transport? It must be borne in mind that the PNTU summarized above put special emphasis in the oversupply of buses and their low capacity utilization as one of the problems of conventional systems. It called for network and fleet 'rationalization'. This led to a design of SITM reforms

[17] The value of travel time is assumed to be 1.3 USD per hour, lower than that estimated by Marquez (2013) for Tunja, Colombia, and lower than the average from his review of the Colombia literature. Fares for each city were obtained from the respective web pages on the 25th of April 2019 and the exchange rate for the same day (3.200 Colombian pesos per USD), and a factor of 2 of the value of waiting time over the value of time. This last parameter is the lower bound of that recommended by practitioners and academics (see Small and Verhoef, 2007, page 53 for a summary of empirical studies) and is very close to that estimated by Marquez (2013) for Tunja of 1.95.

that included a sharp reduction in the operational fleet and a redesign of the network structure into a feeder-trunk configuration.[18] These changes probably affected coverage, frequency and the number of transfers that users had to make to complete a trip, increasing access and waiting times. In addition, although excess supply of buses may be inefficient from an operational perspective, it does offer users a high probability of boarding a bus with empty seats available. By forcing an increase in vehicle occupancy rates, passenger comfort may have been compromised.[19]

If the above effects are true, then the time cost components GCT would have increased with SITM reforms. This was not compensated with a reduction of fares given that in all cities fares where initially set at the previous value for conventional services. Although new vehicles may have offered a higher perceived quality of service for users, it probably did not compensate for more congestion inside buses and the lower availability of empty seats.

Is there evidence for the above hypothesis? From the EUTP data we can estimate the effect of SITM reform on commercial kilometers operated, fleet size and average number of passengers per vehicle.

Table 7 presents the results of analogous difference in difference regressions from those presented above for passengers, but for the logarithm of the number of commercial kilometers. This variable includes those from SITM services as well as conventional services. It can be seen that in all cases the estimated coefficients are negative and statistically significant. The coefficient values imply a reduction between 27% and 34% of commercial kilometers in operation.

Table 8 presents the results for the case of the logarithm of vehicles in

[18]This is similar to the effect derived theoretically by Jara-Diaz and Gschwender (2009) whereby a social planner of a transit system without subsidies will provide a sub-optimal number of buses and an average bus size above what is socially optimal.

[19]The introduction of electronic prepayment systems may also have affected the costs of using SITM services as users must charge their cards periodically to access the system. This entails walking to a charging point and the time taken to charge a card. This is more expensive for low income users since liquidity constraints imply a lower average charging amount and thus more frequent trips to recharge, and also they probably live in areas of the city with a less dense charging network.

Table 7: Estimation results for the logarithm of total transit commercial kilometers, January 2005-March 2018

	excluding Bogota		excluding Bogota and Medellin		excluding Bogota, Pereira and Medellin	
	(1)	(2)	(3)	(4)	(5)	(6)
	All cities	Large cities	All cities	Large cities	All cities	Large cities
SITM	-6.769**	-7.435**	-6.702**	-7.257**	-7.374**	-7.725**
	(1.370)	(1.052)	(1.373)	(1.081)	(1.044)	(0.918)
Obs.	3,338	1,749	3,179	1,590	3,020	1,431
r^2	0.225	0.667	0.230	0.683	0.238	0.714
Δkms	27.5%	30.2%	31.0%	33.5%	31.6%	33.1%

Notes: Robust (Huber-White) standard errors in parenthesis. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. This estimation excludes the municipalities of Envigado, Rioacha and 24 municipalities from the Department of Cudinamarca. Large cities are those with at least five million passengers per month on average in 2007. All models include city fixed effects and monthly time effects. Δkms is the impact of reform on commercial kilometers at the average value of the variable SITM in the sample.

Table 8: Estimation results for the logarithm of the average daily number of vehicles in operation, January 2005-March 2018

	excluding Bogota		excluding Bogota and Medellin		excluding Bogota, Pereira and Medellin	
	(1)	(2)	(3)	(4)	(5)	(6)
	All cities	Large cities	All cities	Large cities	All cities	Large cities
SITM	-6.271**	-7.245**	-6.223**	-7.157**	-6.702**	-7.549**
	(1.105)	(0.552)	(1.114)	(0.579)	(0.972)	(0.437)
Obs.	3,338	1,749	3,179	1,590	3,020	1,431
r^2	0.219	0.837	0.222	0.846	0.228	0.873
Δveh.	25.4%	29.4%	28.8%	33.1%	28.8%	32.4%

Notes: Robust (Huber-White) standard errors in parenthesis. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. This estimation excludes the municipalities of Envigado, Rioacha and 24 municipalities from the Department of Cudinamarca. Large cities are those with at least five million passengers per month on average in 2007. All models include city fixed effects and monthly time effects. Δveh is the impact of reform on the number of vehicles at the average value of the variable SITM in the sample.

operation. It can be seen that there is a negative relationship between reform and the number of vehicles in operation, with a reduction between 25% to 33%.[20]

Both results would indicate that reform is associated with a reduction in supply. Ignoring for the moment the possible off-setting effects of BRT infrastructure, a reduction in the fleet size would imply a reduction in frequency with a concomitant increase in the GCT.[21] BRT corridors may allow buses to run faster than previous services allowing for lower cycle times and thus offering the same frequency with a lower fleet size. However, the length of these corridors is relatively small in these intermediate cities and probably insufficient to compensate for lower coverage and frequency in feeder services as well as the extra waiting time cost of transfers. We will come back to this point further below.

Finally, Table 9 shows the results for model estimates on the logarithm of the average number of passengers per vehicle. In this case we adjust the fleet size to take into account the increase in average bus size of the SITM fleet in comparison to the conventional fleet. We assume for simplicity that a feeder bus of the SITM system is equivalent to two conventional buses, while a trunk SITM bus is equivalent to three conventional buses. With these assumptions it can be seen from the table that the reform coefficient is positive in all cases (demand fell less than fleet capacity). These results could imply higher congestion inside buses and lower seat availability.[22]

[20]Although SITM reform introduced high capacity buses for the trunk services on the BRT corridors, what matters for the GCT is frequency which is related to vehicle numbers not their size. That is why we do not control for the vehicle capacity.

[21]As a first order approximation, a homogeneous reduction of 25% to 33% in the fleet size implies an increase of the same magnitude in the time component of the GCT. Since the results of Table 5 indicate a reduction between 6% and 10% of passengers, this would imply a demand elasticity between 0.2 to 0.3 for transit demand with respect to the frequency time component of GCT.

[22]Controlling for bus capacity may not me sufficient to make an inference regarding seat availability since high-capacity articulated or bi-articulated buses generally have far fewer seats than smaller non-articulated buses of the conventional pre-reform services.

Table 9: Estimation results for the logarithm of the average number of passengers per vehicle, January 2005-March 2018

	excluding Bogota		excluding Bogota and Medellin		excluding Bogota, Pereira and Medellin	
	(1)	(2)	(3)	(4)	(5)	(6)
	All cities	Large cities	All cities	Large cities	All cities	Large cities
SITM	2.169**	2.579*	2.166*	2.569*	2.374**	2.895**
	(0.672)	(0.838)	(0.655)	(0.861)	(0.489)	(0.636)
Obs	3,338	1,749	3,179	1,590	3,020	1,431
r^2	0.211	0.346	0.208	0.342	0.210	0.360
Δpax/veh	8.8%	10.5%	10.0%	11.9%	10.2%	12.4%

Notes: Robust (Huber-White) standard errors in parenthesis. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. This estimation excludes the municipalities of Envigado, Rioacha and 24 municipalities from the Department of Cudinamarca. Large cities are those with at least five million passengers per month on average in 2007. All models include city fixed effects and monthly time effects. Feeder vehicles of SITM are assumed to have double the capacity of a regular TPC vehicle, while trunk SITM vehicles are assumed to have three times the capacity of a TPC vehicle. Δpax/veh is the impact of reform on passengers per adjusted capacity vehicle at the average value of the variable SITM in the sample.

4.4 Additional evidence

The results presented in the last section are consistent with the hypothesis that SITM reform reduced the fleet and the commercial kilometers operated by the aggregate transit sector in each city as well as increasing the average demand per vehicle. Unfortunately, we do not have direct evidence for the impact of these changes on the GCT of using transit services and thus demand. However, there is circumstantial evidence for this effect from secondary sources.

For example, in Bucaramanga we already showed above in Figure 1 that its SITM, called *Metrolinea* reduced the number of vehicles in operation from close to 2,000 before reform to 1,400 immediately after reform (in 2018 the total transit fleet was just above 1,200). In addition, the number of routes fell from 103 before reform to 62 with Metrolinea. The result was probably higher access costs, more transfers and higher waiting time costs.

Table 10 presents information on the number of trip segments (different services) that users on average make to complete a trip in five Colombia cities. It also presents subjective opinions regarding waiting and travel times as well as frequency. Among these cities, only Bucaramanga and Medellin have a BRT system, although in the case of Medellin it is part of an integrated system that includes metro, cable-cars and light-rail.

From the table it can be seen that in Bucaramanga users make more transfers than in other cities, even more than in Medellin that has a multimodal integrated system.[23] This is directly related to the feeder-trunk configuration of the SITM system.

Table 10: Trip segments and satisfaction with several trip attributes

	Valledupar	Sincelejo	Neiva	Bucaramanga	Medellín
Average trip segments	1.002	1.050	1.082	1.308	1.178
	Satisfaction with service attributes				
Travel time	3.2	3.5	3.3	3.0	3.6
Waiting time	2.8	2.5	3.0	2.8	3.5
Frequency	3.2	3.6	3.2	2.9	3.6
Comfort	3.4	4.0	3.3	3.1	3.6

Sources: Ministerio de Transportes, Encuestas de Monitoreo del Impacto de Inversiones en Proyectos SITM y SETP. The scale for satisfaction with service attributes ranges from 1 (very bad) to 5 (very good). See World Bank (2018), Medium-sized cities BRTs – Technical Assistance Colombia, Informe Final, (Project ID: P166117).

The increase in transfers, together with the fleet and route reduction, may explain why subjective valuation of frequency, waiting and travel times are so low in Bucaramanga compared to the other four cities.[24] Comfort also ranks low, even compared to cities with old fleets run by informal operators as in Valledupar and Sincelejo. This is consistent with the hypothesis that under an SITM passengers face higher congestion inside buses and a lower probability of finding an empty seat.

[23] Zima-Ingenio Colectivo SAS (2014) indicate that in Bucaramanga 54% of SITM users make at least one transfer, while in Cali the proportion is 65%.

[24] The low qualifications of waiting times in the case of Sincelejo and Valledupar may be related to the climate in those cities, making waiting in the streets very uncomfortable. This points to the need to interpret the information of Table 10 with care since it does not control for city-specific effects.

Another suggestive piece of evidence is that in the case of Bucaramanga, only 17.3% of Metrolinea (SITM) users consider the system better than the conventional public transport services while 46.6% consider the SITM worse than these conventional services.[25]

Zima-Ingenio Colectivo SAS (2014) summarize the results of surveys of SITM perceptions in four cities: Pereira, Cali, Bucaramanga and Barranquilla. Non-users of the SITM cite lack of coverage or convenience for their trip as the main reason for not using the systems. But they also cite long waiting times in the SITM and high-congestion inside buses for trunk services as additional motives.

The hypothesis developed above is also consistent with information obtained by the author from the managers of Metroplus, the BRT system in Medellin. Two feeder zones from that city were reformed several years ago (Cuenca 3 and 6) by Metroplus in an attempt to modernize services and integrate them to the BRT infrastructure. Services were tendered and conventional services were eliminated. However, due to cost considerations, the number of buses of the new integrated services was reduced from 194 operating before reform to 108 in Cuenca 3, and from 361 prior to reform to 259 in Cuenca 6. In addition, 33 services were eliminated. Ex-post demand was much lower than expected in each zone. The reasons given by personnel from Metroplus is that demand was discouraged by higher access costs to the new services (greater walking distance), lower frequency, the need to transfer to the BRT system to complete a trip and a reduction in the probability of finding an empty seat. This is precisely the same effect we conjecture happened with the SITM reforms.

Another interesting evidence is provided by BID (2016). This report presents the results of a survey of public transport use by poorer individuals in Cali and Lima (Peru). In this last city, a BRT system called 'Metropolitano' began operation in October 2010. The study concludes that in Cali 58% of surveyed individuals prefer the competitive conventional services rather than the SITM due to low quality of service, low speed (particularly in feeder

[25]See answers to question 24 of the Encuesta de Monitoreo del Impacto de Inversiones en Proyectos SITM y SETP, Ministerio de Transportes (2016). The fare is the same in both systems so the answers are not influenced by any financial consideration.

services), waiting times and long queues. These reasons are related to the arguments we presented for the increase in GCT. Something similar was noted to have happened in Lima.

4.5 Why was Phase I and II of Transmilenio different?

Phase I and II of Transmilenio seems to have been a more successful experience. Demand levels were very close to those projected at the reform stage (EMBARQ, 2017). Operational subsidies were not required in the case of Transmilenio. What differentiates this case from the SITM reforms in intermediate cities?

One important difference is the city size. With seven million inhabitants and over 145 million trips per month, it seems more likely to be able to create successful BRT infrastructure over strategic corridors that have a high density of potential demand. Related to this point is the fact that the BRT corridors in Bogota were much longer than in the intermediate cities. It began with 42.3 kilometers and now are over 112 kilometers. Therefore, the increase in speed achieved over this infrastructure have a large impact on in-vehicle travel times, helping to compensate for transfers or higher waiting times. Therefore, reforms in larger cities, where trips and dedicated infrastructure are longer, are, a priori, more likely to result in a reduction in the GCT, increasing demand and user satisfaction.[26]

In contrast, in intermediate cities in Colombia the SITM infrastructure was smaller. From Table 1 it can be seen that with the exception of Cali, all BRTs have less than 20 kilometers in length, with just 10.7 in the case of Cartagena. Therefore, the potential in-vehicle time savings are smaller and may not compensate for extra access and waiting times.[27]

[26]Interestingly, BID (2016) reports that poorer individuals in Lima and Cali tend to use the BRT system more when their trips are longer. This is a rational self-selection of passengers if in-vehicle travel time reductions over the BRT infrastructure are larger for longer trips.

[27]For example, for a 10 kilometer trip in the BRT corridor, with pre-reform speeds of 15 kilometers per hour, and an increase of 20% in bus velocity, the reduction of in-vehicle time would only be 6.7 minutes. Since waiting time costs are at least double the value of in-vehicle time, it would take just an additional 3.3 minutes of access or waiting time –due

5 Conclusions

In this paper we have shown that SITM reforms in intermediate cities in Colombia are associated with a decrease in fleet size, commercial kilometers operated, and ultimately, the total number of passenger that use formal transit services. We conjecture that this was due to an increase in the GCT of transit as a consequence of excessive fleet rationalization and network restructuring (towards a feeder-trunk configuration). There are two possible explanations of why reforms had this faulty design.

First, an excessive optimism born form the early Transmilenio experience in Bogota, together with a diagnosis that the traditional transit services suffered from 'excess-supply', made reform planners less attentive to the determinants of demand and the impact that fleet reduction and network design would have on the GCT.[28] It is also probable that during this period the demand for transit services become more elastic as a consequence of the growth of informal taxi services, in particular mototaxis, and planners were as of yet unaware of this phenomenon. The point is that in the future more careful demand modelling is called for when designing these and other reforms.

Second, SITM reforms were expensive. As mentioned in the introduction, they were envisaged as high quality full BRT systems with technology, fleet renovation, infrastructure and formalization of operators and labor relations. In addition, the systems had to fund the regulator (*Entes Gestores*) as well as conventional fleet scrapping programs. Since raising fares was not politically feasible and there were no operational subsidies associated with the PNTU, the only variable available to contain costs was fleet 'rationalization'. We do not have evidence on whether the financial restriction generated by the high costs of an SITM system forced planners to reduce the fleet size beyond

to lower coverage, lower frequency or more transfers– for a passenger to be made worse off after the reform. Even if bus speeds increase by 40% it would still just take 5.7 minutes of additional access and waiting time for the passenger to be made worse off. In contrast, for a 30 kilometer trip in the corridor, the equivalent values of additional access and waiting times would be 10 and 17 minutes, respectively.

[28]The author's own experience in Neiva, Colombia, in the context of the design of a SETP type reform, points in this direction. There, planners projected future transit demand and then optimized fleet size and route structure without considering the feedback effect that this operational plan would have on expected demand levels. The SETP reform in this city has not been implemented yet.

what they considered to be optimal. However, we do know from conversations with managers of current SITM systems that they consider current fleet size, routes and frequency to be insufficient. However, financial restrictions preclude increasing supply.

After almost two decades since the PNTU was introduced it is time to rethink this policy. In the case of cities that already have a SITM in operation, the options are rather limited. To increase demand, frequency and coverage must increase, but this is costly. Realistically, the only way to fund the needed increase in supply is with some type of capital or operational subsidy.[29] Another option worth exploring is for feeder services to use the BRT corridors and so passengers do not have to make transfers between feeder and trunk services.

What about future reforms and the SETP? These last types of reform for smaller cities do not consider dedicated infrastructure for buses. Therefore, the fleet and network rationalization of these reforms is likely to produce and even greater reduction in demand compared to the SITM, where at least some in-vehicle time reduction can be expected for passengers in trunk services.

For SETP and future SITM reforms there are several options. First, introduce some type of capital or operational subsidy in order to maintain and adequate fleet size and thus frequency and coverage levels. Second, reduce the costs of these reforms by scrapping or postponing some of their features such as world class fleet management systems, electronic prepayment cards, or even the ambitiousness of the fleet renovation policy (possibly allowing to renovate for used but newer buses).[30]

This last recommendation in essence amounts to changing the design of reforms from full BRT systems to light BRT systems. We believe that absent subsidies, this last recommendation is sound for smaller and intermediate cities. In fact, there are several successful experiences in the region where the policy has been to invest in dedicated 'open' infrastructure and buses of

[29] An interesting example is Cali that introduced a type of congestion charge two years ago with the explicit objective of raising revenues to subsidize its SITM.

[30] Certainly, the cost of running the regulatory agency should not be part of the system's cost.

conventional services enter and exit these corridors without further changes from reform. This policy is guaranteed to benefit users and operators alike as the higher bus speeds allow for lower cycle times, higher frequencies and lower waiting and in-vehicle times. Since corridors are open, passengers do not make additional transfers. The experience in Buenos Aires (Argentina) and smaller cities such as Leon (Mexico) and Concepción (Chile) are worth analyzing in this respect.

What has been documented for intermediate cities in Colombia and its possible explanation seems to be a much wider phenomenon in the region. Transit reforms in many cities in Latin America have faltered or faced severe difficulties, including Santiago, Panama and Lima. In all of these cases, the same pattern seems to emerge. A reform is designed to modernize transit services by formalizing operators and labor relations, renovating fleet, and introducing technology for fleet management and payment systems. Since these reforms are costly and no operating subsidies are considered in the design stage, implicitly the reform is funded by 'rationalizing' the fleet and route network. The lack (or insufficiency) of dedicated bus infrastructure makes matters worse, as there are no gains in operational speeds for the new services.

The above dynamics explain the Transantiago reform in Santiago, Chile (Gomez-Lobo, 2012). Fleet size was reduced from some 8,000 buses prior to reform, to 5,600 when the system became operational in February 2007 (Beltran, et al., 2013). The dramatic lack of capacity of the system –evidenced by long waiting times, excessive transfers, queues at bus stops and over-crowded buses–produced a social and political crisis that reverberates to this day.[31] To revert the crisis it was necessary to increase fleet size. However, since the new system was much more expensive than the previous system, an operational subsidy was required to fund the additional buses. Currently, the fleet size is over 6,500 buses and a yearly subsidy of close to $700 million dollars (amounting to 45% of operational costs) is required to fund the system.

[31]The reduction in fleet size was not the only problem with the reform, as discussed in Gomez-Lobo (2012) but an increase in fleet size was a necessary condition to resolve the crisis. An important fraction of the post reform fleet were high capacity articulated buses. But besides being perceived as uncomfortable by users due to their lack of seats, frequency and waiting times were still affected.

The SIT in Lima seems to be another case. This reform was an attempt to modernize the transit system outside the BRT corridor of Metropolitano. Poole Fuller (2017) makes essentially the same argument presented above of an increase of the GCT due to the SIT reform. He reports that in the first complementary corridor, supply decreased from 1.100 vehicles prior to reform to 153 post-reform. Interestingly, Poole Fuller (2017) recognizes the lack of operational subsidies as the possible reason for this decrease in supply. He also makes a similar argument of his review of the SITP reform in Bogota (outside of the Transmilenio system).

In sum, the Colombian experience with SITM reform evaluated in this paper also provides important lessons for transit reforms in the Latin American region and the rest of the developing world.

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A Placebo regressions and the common trend assumption

As discussed in the text, in order to attribute the econometric results on transit demand to the treatment (SITM reform) we must make the common trend assumption among cities. That is, both treated and untreated cities must exhibit the same time trend for demand prior to reform, although demand levels can differ. This implies that the effects of motorization rates, economic growth and other confounding factors affect all cities roughly in the same way (proportional to demand).

One way to test the common trend assumption is by restricting the sample to larger cities, making the control group and the treatment group more homogeneous. As seen in the results above, restricting the sample to larger cities increases the significance of the negative impact of a SITM on transit demand.

Another alternative is to estimate "placebo" regressions. These regressions use a time period prior to reform and artificially generate a fictitious treatment variable. If the false treatment variable is statistically significant then the common trend assumption is rejected and the results of the main models are biased.

In the present application there are difficulties in estimating placebo regressions because reforms where introduced at different time periods for each city, beginning with Pereira in 2006 and ending with Cartagena in 2016. Therefore, there is no clear sample period 'before' reform. In what follows we define the 'pre-reform' period as years 2005, 2006, 2007, 2008 until February 2009 when the SITM in Cali began operation. Data for Pereira is dropped from the sample, and a fictitious reform variable is assumed beginning on January 2007 for Cali, Bucaramanga, Barranquilla, Medellin and Cartagena. The pre-reform period is thus split into a untreated period (2005 and 2006) and a treated period (2007- February 2009) for the above mentioned cities.

With these definitions, the models were estimated for the 2005-February 2009 period where in some estimations Medellin was also excluded from the sample. The results are shown in Table 11. It can be seen from this table that when the control group includes all cities (except Bogota, Pereira and Medellin in the last four columns) the coefficient of the false SITM reform variable is positive but not statistically significant. When the control group is restricted to cities with more than five million passengers per month on average in 2007, the parameter is negative but again not statistically significant. Therefore, we do not find evidence to reject the common trend assumption.

In order to increase the sample period for the placebo regressions, Table 12 presents the results excluding Cali, which allows for the sample to be increased until March 2010 (since in April the SITM in Bucaramanga began operations). In this case, the fictitious SITM reforms are assumed to begin operation in January 2008.

The results of Table 12 are very similar to those of Table 11 and again we find no evidence to reject the common trend assumption. These results lend support to the models and interpretation of the results in the text.

Table 11: Estimation results for placebo regressions on the logarithm of total transit passengers, January 2005-February 2009

	excluding Bogota and Pereira		excluding Bogota, Pereira and Medellin	
	(1)	(2)	(3)	(4)
	All cities	Large cities	All cities	Large cities
SITM	3.128	-3.295	2.916	-2.788
	(3.368)	(2.679)	(3.356)	(2.652)
Obs.	1,000	500	950	450
r^2	0.190	0.161	0.216	0.241

Notes: Robust (Huber-White) standard errors in parenthesis. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. This estimation excludes the municipalities of Envigado and Rioacha. Large cities are those with at least five million passengers per month on average in 2007. All models include city fixed effects and monthly time effects. It is assumed that an SITM reform began in January 2007 for those cities that eventually had a reform.

Table 12: Estimation results for placebo regressions on the logarithm of total transit passengers, January 2005-March 2010

	excluding Bogota, Pereira and Cali		excluding Bogota, Pereira, Cali and Medellin	
	(1)	(2)	(3)	(4)
	All cities	Large cities	All cities	Large cities
SITM	5.925	-4.616	5.410	-4.600
	(4.770)	(2.671)	(4.489)	(2.768)
Obs.	1,197	567	1,134	504
r^2	0.254	0.192	0.278	0.281

Notes: Robust (Huber-White) standard errors in parenthesis. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$. This estimation excludes the municipalities of Envigado and Rioacha. Large cities are those with at least five million passengers per month on average in 2007. All models include city fixed effects and monthly time effects. It is assumed that an SITM reform began in January 2008 for those cities that eventually had a reform.