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Transit reforms in intermediate cities of Colombia: An ex-post evaluation☆

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A B S T R A C T

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 Santiago, Lima and Bogota (SITP).

1. Introduction

Colombia was a pioneer in transit reform. Although Curitiba in Brazil had developed a BRT system since the 1970s — 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 km 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., 2005; Carrigan et al., 2017). It was followed by two more stages, expanding the exclusive corridors by 48.9 km between 2002 and 2006 (Phase II) and by an additional 21.7 km 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

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[1] According to Mejía-Dugand et al. (2013), who study the dissemination process of BRTs in Latin America, it was Transmilenio that produced the 'cascade of change' that prompted its widespread adoption around the world. 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. Section 2 presents a discussion of the relationship between this definition and transit reforms in intermediate cities of Colombia.

[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.

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well as the rest of the world. Transmilenio generated an optimism among policymakers in developing countries that it was possible to improve mobility and increase quality of life 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).[3] 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 people from 55 cities) in Latin America alone.[4] 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.[5]

Despite the scale of BRT reform 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. Most of the existing literature deals with the impact of BRTs on land values, environmental externalities, access for the poor, distributional issues or the performance of the BRTs in terms of ridership, travel times and other operational variables.[6] None of these studies analyze the aggregate net impact on mobility of these reforms. Notable exceptions include Echeverry et al. (2005) for Phase I of Transmilenio and Carrigan et al. (2017) for reforms in Bogota, Mexico City, Johannesburg and Istanbul. However, these studies undertake an ex-post Cost-Benefit Analysis and do not evaluate their impact taking into account a suitable control group.[7]

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 concession to a private operator in 2015, just two years after it was fully implemented.[8] 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 (Doña and Morandé, 2007; Gómez-Lobo, 2012, and Gallego et al., 2013).[9] The experience in Lima and several cities in Mexico is also complex. Even in Colombia, a 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. We document below that transit reforms in intermediate cities of Colombia are also facing financial and operational difficulties not envisaged when they were designed, putting pressure on municipal governments of these cities that now are having to fund increasing operational deficits.

Why have some reforms after Transmilenio not replicated its success? Rather, many experiences in Latin America and in Colombia in particular seem to be rather negative with lower than expected ridership levels and circumstantial evidence that points 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 is available with monthly information on transit demand levels, number of vehicles 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 new BRT services.

In this paper we use this data to evaluate the impact of transit reforms in intermediate cities of Colombia on ridership and supply. Since not all cities implemented a reform nor, in the cities that did, at the same time, we are able to use a staggered difference in difference panel data model from the policy evaluation econometric literature to estimate the impact of these reforms.[10] This methodology uses a suitably defined control group of cities to contrast with those that implemented reform and thus can potentially identify the impact of these reforms by controlling for general macroeconomic and other confounding factors (rising motorization rates, for example). We find that transit reforms in intermediate cities in Colombia are associated with an important decrease in fleet size and commercial kilometers supplied. In turn, we find that citywide ridership levels (conventional plus the new BRT services) fell after reform. This is particularly troubling, since it points to a decrease in the attractiveness of the public transport system for users

[3] To be precise, Quito had already implemented a trolleybus BRT system by 1996. However, other corridors in that city as well as in Guayaquil were built after Transmilenio.

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

[5] As discussed further below these reforms were a mixture of city-wide efforts to replace the chaotic conventional transit services with formal operators and thus reduce the perceived ‘over-supply’ of these services, together with a BRT reform in some central corridors. In the rest of the paper we will refer to these as SITM reforms but it should be borne in mind that these combined BRT infrastructure and operation with city-wide transit reorganization.

[6] Literature reviews of BRT experiences include Deng and Nelson (2011), Hidalgo and Gutierrez (2013) and Nikitas and Karlsson (2015).

[7] 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.

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

[9] 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’).

[10] See Goodman-Bacon (2018) for an analysis of the staggered difference in difference model.

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 reforms in Colombia 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 compensate 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, Lima and the SITP reform in Bogota.

To the best of our knowledge, this paper is the first attempt to evaluate the transit reforms in intermediate cities of 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 its national urban transport strategy 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 challenges faced by 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 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. Transit reforms in Colombia

As discussed above, the successful launch of the first phase of Transmilenio in 2000 was a catalyst for transit reforms 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 of the country.

This policy was formalized through several laws, regulations and programs, starting with the document CONPES (2002).[11] 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 urban transit strategy 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.[12]

CONPES (2003) complements the earlier document and provides further guidelines of the urban transport policy. This policy called for fare and operational integration 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, it established that the new transit systems (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 the definition presented in the introduction, the national urban transport policy envisaged top-of-the-line 'full' BRT systems for transit reforms in intermediate cities. However, these reforms also contemplated the city-wide formalization of operators, rationalization of the conventional bus fleet and the restructuring of the routes beyond the limits of the BRT network. In general, all BRT reforms consider to some extent the rationalization of routes and fleet outside the system. For example, tendered contacts for phase I and II of Transmilenio in Bogota required the scrapping of over 5,000 of the 22,000 conventional buses operating in the city.[13] Therefore, as far as transit reforms are concerned there is no clear distinguishing line between a pure BRT reform and more encompassing city-wide reforms, with a continuum observed in practice. The BRT literature (e.g. Hidalgo and Gutierrez, 2013; BRTdata.org) considers all transit reforms as BRT, including Transantiago, Mibus (Panama) and more recently the SITP in Bogota, that can scarcely be considered as BRTs given the dearth of dedicated bus infrastructure. This ambiguity raises the question of where exactly do the SITM reforms in intermediate cities of Colombia fit in this continuum. Here we postulate that these reforms were a

[11] 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.

[12] 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 except for a brief discussion of the probable consequences of these reforms in the conclusions.

[13] Interestingly, only 1,410 buses were eventually scrapped while the rest were relocated to other corridors not served by Transmilenio (Echeverry et al., 2005). This may explain in part why the Transmilenio experience was more successful than reforms in intermediate cities. We will come back to this point further below.

mixture of BRT with city-wide reforms an issue that must be borne in mind when interpreting the results of this paper.

On the funding side, the national urban transport policy 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.[14]

It is important to note that the national policy 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.[15] 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, the new (SITM) transit systems began operation in the main regional capitals of Colombia: Pereira (2006), Cali (2009), Bucaramanga (2010), Barranquilla (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.[16] Concession contracts were tendered to private operators and for the financial administration of the payment system. Depending on the city, between two to four operating contracts were tendered for trunk and feeder services. In all cases fares for users as well as payment to operators are regulated in the concession contracts. The *Ente Gestor* undertakes network planning and determines the operational plan. 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, promoting the creation of real operating companies instead of informal organizations affiliating routes and reducing 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 new 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 reform.

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 national urban transport policy 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 revenues even further (Fedesarrollo, 2013).

Today, all the new reformed systems have demand short-falls that affect their financial and operational sustainability.[17] 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 Colombian national statistical office. 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 the database. Municipalities belonging to a metropolitan area were aggregated. The result was a database comprised of 22 cities or metropolitan areas with information from January 2005 until March 2018 (excluding Cudinamarca) or from January 2007 to March 2018 including Cudinamarca.

Table 3 presents descriptive statistics for each urban area. It must be borne in mind that these figures are for all transit services, both conventional as well as those from the new formal systems (SITM) in those cities that implemented a reform. The last two

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

[15] According to Rodriguez and Mehndiratta (2014), the funding of the *Ente Gestor* takes up 7.0% of fare revenues in Barranquilla, Bucaramanga and Cali and 3.5% in Pereira. Infrastructure expenses take up 9.0% of fare revenues in Barranquilla, 12.0% in Bucaramanga and 3.0% in Cali.

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

[17] 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.

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	–
Number of operators	2	2	4	3[a]	3	2
Speed (kms/h)	22	20 (2012)	17.8 (2014)	–	16	20

Source: BRTdata.org. Last accessed May 6th, 2019.
[a] In the case of Cartagena, one contract is a public operator, Operador Transcaribe, after two failed attempts to tender this contract to a private operator. In all other case, operators are private companies, usually comprised of traditional incumbent operators who formed a formal operating company.

Table 2
Ex-ante projections and effective demand for SITM systems (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 for 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 266.2 thousand passengers per day, less than 60% of expected demand.

columns of Table 3 are the total population and average household per capita income in each locality at the beginning of the sample period (2005).

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.[18] 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 a transit reform, or when they did, not at the same time. Thus, we can use a staggered difference in difference panel data model to identify the impact of SITM reform.

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,

[18] 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.

Period	Passengers (month) 2007–2018	Vehicles in service (daily) 2007–2018	Kilometers operated (month) 2007–2018	Total population 2005	Household per capita income (USD/month) Jan. 2005
Armenia	1,689,443	323	1,811,417	280,930	n.a.
Barranquilla	25,821,596	3,236	16,263,049	1,709,490	411
Bogotá D.C.	146,355,431	14,044	76,927,510	6,840,116	862
Bucaramanga	10,366,237	1,485	10,707,109	1,024,350	344
Cali	22,779,925	2,483	16,247,893	2,522,068	453
Cartagena	11,716,746	1,403	6,176,049	892,545	311
Cúcuta	7,940,334	1,644	9,347,742	724,790	244
Cundinamarca	10,546,852	1,788	10,951,516	959,816	182
Florencia	442,547	90	372,794	143,871	242
Ibagué	6,242,525	1,021	6,065,796	498,401	438
Manizales	5,932,998	789	4,173,700	425,393	334
Medellín	36,452,768	4,641	19,537,543	3,087,868	262
Montería	1,084,321	147	896,364	378,970	289
Neiva	2,439,814	535	3,639,843	316,033	178
Pasto	3,077,436	480	1,901,913	382,618	299
Pereira	7,296,376	717	4,528,464	622,855	536
Popayán	2,992,759	563	4,028,302	257,512	n.a.
Quibdó	583,597	105	417,435	112,886	140
Santa Marta	9,995,147	745	4,001,694	415,270	344
Sincelejo	592,445	105	417,435	237,618	n.a.
Tunja	1,968,675	450	2,363,547	154,096	98
Valledupar	818,514	161	971,424	354,449	180
Villavicencio	4,945,866	947	4,745,249	380,222	371

Source: DANE, Colombia. Passengers, vehicles and kilometers from the EUTP. 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. Population figures come from the 2005 census. Household income per capita were calculated based on the January 2005 Household Survey (Encuesta Continua de Hogares, 2005) and the average exchange rate reported by the Colombian Central Bank (Banco de la República) for January 2005 was used to convert to US dollars.

Table 4
Results for the logarithm of total passengers per month, 2007–2018.

	excluding Bogota		excluding Bogota, and Medellin	
	(1)	(2)	(3)	(4)
	All cities	Large cities	All cities	Large cities
SITM	−2.709*	−2.953**	−2.694*	−2.861**
	(1.106)	(0.662)	(1.117)	(0.714)
Obs.	2,709	1,620	2,834	1,485
r^2	0.128	0.557	0.130	0.594
Δpax	−10.1%	−11.0%	−11.5%	−12.2%

Notes: Robust (Huber–White) standard errors in parenthesis (* $p < 0.05$, ** $p < 0.01$). 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 for the treatment period for cities that implemented these reforms.

Table 5
Results for the logarithm of total passengers per month, 2005–2018.

	excluding Bogota		excluding Bogota and Medellin	
	(1)	(2)	(3)	(4)
	All cities	Large cities	All cities	Large cities
SITM	−1.571	−2.261**	−1.509	−2.119*
	(0.967)	(0.629)	(0.985)	(0.671)
Obs.	3,338	1,749	3,179	1,590
r^2	0.202	0.634	0.208	0.672
Δpax	−6.4%	−9.2%	−7.0%	−9.8%

Notes: Robust (Huber–White) standard errors in parenthesis (* $p < 0.05$, ** $p < 0.01$). 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 for the treatment period for cities that implemented these reforms.

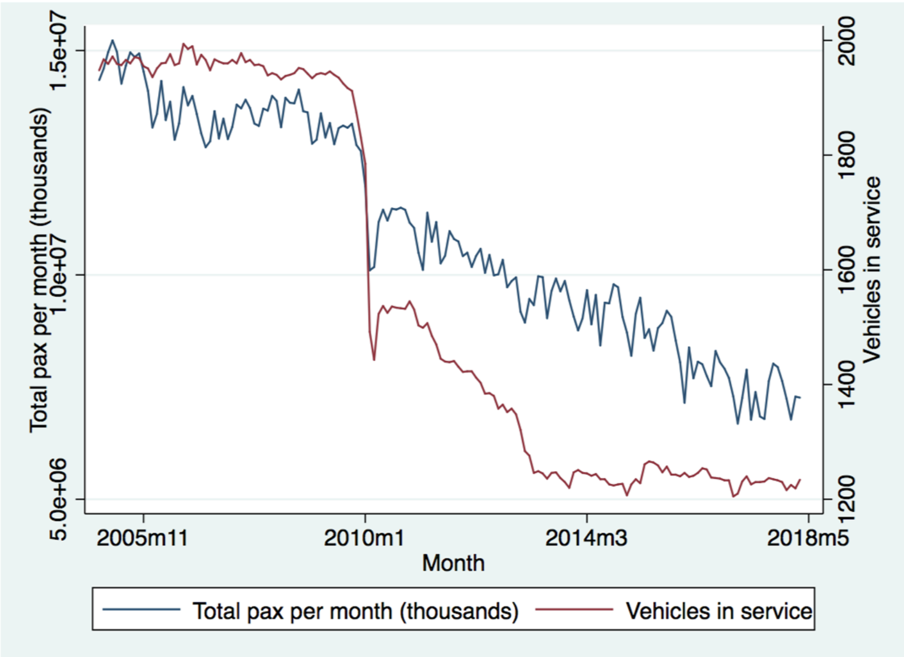

Fig. 1. Total passengers per month and number of daily vehicles in operation, Bucaramanga 2005–2018.
EUTP, DANE.

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 BRT 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.[19]

The *SITM* variable is bounded between 0 and 1, and represents the relative importance of the trunk BRT 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

[19] This panel data model is widely used as a difference in difference estimator. Since treatment occurs at different dates for different observations it is also called a staggered difference in difference model. Despite its popularity the properties of this model are just beginning to be studied. Goodman-Bacon (2018) shows that the parameter β will be a weighted average of several difference in difference comparisons: cities with SITM compared to cities that never had a reform, cities with a reform compared to cities that already introduced a reform earlier in the sample period as a control group or even cities with reform compared to cities that have yet to implement a reform as a control group. These weight do not have an intuitive interpretation.

Table 6
Waiting time cost as proportion of fares, intermediate cities that implemented a SITM reform, 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.

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

	excluding Bogota		excluding Bogota and Medellin	
	(1)	(2)	(3)	(4)
	All cities	Large cities	All cities	Large cities
SITM	−6.769**	−7.435**	−6.702**	−7.257**
	(1.370)	(1.052)	(1.373)	(1.081)
Obs.	3,338	1,749	3,179	1,590
r^2	0.225	0.667	0.230	0.683
Δkms	−27.5%	−30.2%	−31.0%	−33.5%

Notes: Robust (Huber-White) standard errors in parenthesis ($* \ p < 0.05$, $** \ p < 0.01$). 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 for the treatment period for cities that implemented these reforms.

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	
	(1)	(2)	(3)	(4)
	All cities	Large cities	All cities	Large cities
SITM	−6.271**	−7.245**	−6.223**	−7.157**
	(1.105)	(0.552)	(1.114)	(0.579)
Obs.	3,338	1,749	3,179	1,590
r^2	0.219	0.837	0.222	0.846
Δveh.	−25.4%	−29.4%	−28.8%	−33.1%

Notes: Robust (Huber–White) standard errors in parenthesis ($* \ p < 0.05$, $** \ p < 0.01$). 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 for the treatment period for cities that implemented these reforms.

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	
	(1)	(2)	(3)	(4)
	All cities	Large cities	All cities	Large cities
SITM	2.169**	2.579*	2.166*	2.569*
	(0.672)	(0.838)	(0.655)	(0.861)
Obs	3,338	1,749	3,179	1,590
r^2	0.211	0.346	0.208	0.342
Δpax/veh	8.8%	10.5%	10.0%	11.9%

Notes: Robust (Huber-White) standard errors in parenthesis (* $p < 0.05$, ** $p < 0.01$). 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 for the treatment period for cities that implemented these reforms.

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).

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.

in operation or not gave similar results as those reported below but parameters had lower significance levels in some estimations. Using a discrete variable does not consider the growth of these systems over time since their inauguration. For example, Metrolinea in Bucaramanga began operation in December 2009 with 100 trunk buses. Phase II of this reform began in July 2012 with over 100 new trunk buses in operation. A discrete variable will not capture these incremental changes and therefore, as an imperfect proxy of system size, its not surprising that standard errors are higher when this variable is used.[20]

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.[21]

The model was also estimated using different samples. Some estimations are for the entire period January 2005 to March 2018 excluding the Department of Cudinamarca as most municipalities in this Department 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 include the reform in Pereira that began operation in August 2006.

In both samples, the model is estimated for all cities and also for a sub-sample 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 across cities.

Bogota was also excluded from the sample. Being the largest city in Colombia and where trip length are probably longer, together with a much larger bus priority infrastructure, the effects of a BRT may be quite different from those in smaller cities. We will come back to the case of Bogota further below as well as some comments in the conclusions regarding a more recent transit reform in that city called SITP.

The case of Medellin is also complex. The BRT 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 had 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. Table 5 includes the whole sample but eliminating the data for 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). The absolute value of the coefficient does not say much since the SITM variable is continuous rather than discrete. In order to evaluate the impact of reform, this coefficient can be multiplied by the mean value of the SITM variable among cities that had a reform (after the reform was implemented) in order to obtain an average effect on demand. This is precisely what is shown in the last row of the table, using the descriptive statistics presented in Annex A. The SITM coefficients imply a reduction in demand between 9% and 12% depending on whether Medellin is included or excluded from the sample.

[20] Results using a discrete dummy variable marking the initial inauguration of each system are available upon request from the author. It should also be noted that since results are similar using a discrete dummy variable to using the proportion of BRT trunk vehicles, possible endogeneity issues concerning the use of this last variable should not be a problem.

[21] The maintained assumption therefore is that fares are highly correlated across cities and will therefore be controlled for by the monthly time dummies. This is a reasonable assumption if fares depend on nation wide shocks such as fuel prices. In all cities, fares for both the conventional services as well as SITM services were regulated. SITM services usually began with a fare equal to the one for conventional services. This was an explicit goal in some cases (see www.transcaribe.gov.co/transcaribe/historia).

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 fall in demand between 6% and 10%.

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

Before asserting this last conclusion we must assure that the results are not due 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 B 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.

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 Bucaramanga shown in Fig. 1. It can be seen that the total number of passengers dropped from around 14 million per month 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 transit demand. As is well know, this demand will depend on fares, access, waiting and in-vehicle times, 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).[22] 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.

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 time as a fraction of fares for each city in April 2019.[23] A one minute increase in waiting times is equivalent to a 5%-7% increase in fares. If waiting times increase by 5 min this is equivalent to a 30% increase in fares and double this amount for an extra 10 min wait. Therefore, extra waiting time implies a significant increase in the GCT of transit services. Access time is also costly, roughly similar to waiting time costs (Small and Verhoef, 2007).

What impact could the SITM reforms have had on the generalized cost of travel on public transport? It must be borne in mind that Colombia's national urban transport policy 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 that included a sharp reduction in the operational fleet and a redesign of the network structure into a feeder-trunk configuration beyond the BRT network. These changes probably affected coverage, frequency and the number of transfers that users had to make to complete a trip, increasing access and waiting time costs. 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.[24]

If the above effects are true, then the time cost components of the GCT of transit 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 data we can estimate the effect of 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

[22] 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.

[23] 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 Colombian 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.

[24] 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.

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 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%.[25]

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.[26] 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 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.[27]

A final question is how the above results relate to the theoretical literature on BRT infrastructure. This literature points to the welfare improving features of bus only lanes or BRT systems. Kutzbach (2009), for example, shows that reserved bus lanes can improve consumer surplus. However, his model does not include a financial constraint that can limit the fleet size. In Basso and Silva (2014), bus only lanes also increase welfare in their analysis of Santiago and London but in this case bus fares are endogenous and therefore adjust to fund the optimal fleet size. Basso et al. (2019) show that BRT can be a Pareto improvement but in their model frequency and the price difference between bus and car modes are also optimized. None of these models consider the fact that reform may increase operational and capital costs by requiring the formalization of labor relations, better quality buses and modern technology. The paper that comes closest to explaining our results is Jara-Diaz and Gschwender (2009) where 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.

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 Fig. 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 that users on average make to complete a trip in five Colombia cities.[28] 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.[29] This is directly related to the feeder-trunk configuration of the new SITM system.

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.[30] 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.

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[25] Although each 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. Therefore we do not control for vehicle capacity in these regressions.

[26] 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 and −0.3 for transit demand with respect to the frequency time component of GCT.

[27] Controlling for bus capacity may not be sufficient to infer an impact on seat availability since high-capacity articulated or bi-articulated buses generally have fewer seats than smaller non-articulated buses of the conventional pre-reform services. Therefore, the above results may underestimate the negative effects of reform on seat availability.

[28] By trip segments we refer to the different services that users must take to complete a trip. For example, if a passenger must transfer from one bus to a different bus to complete the trip, then the trip will have two segments; three if the passenger must take three different buses, and so on.

[29] 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%.

[30] 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.[31]

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 AMVA, the metropolitan transport authority in Medellin. Two feeder zones from that city were reformed several years ago (Cuenca 3 and 6) in an attempt to modernize services and integrate them to the Metro or 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 AMVA is that demand was discouraged by higher access costs to the new services (greater walking distance), lower frequency, the need to make transfers 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). 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 services), high waiting times and long queues. These survey results are consistent with the increase in the GCT argument presented above.

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, 2009). 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 km and now are over 112 km. Therefore, the increase in speed achieved over this infrastructure has 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.[32]

In contrast, in intermediate cities in Colombia the BRT infrastructure is smaller.[33] From Table 1 it can be seen that with the exception of Cali, all BRTs have less than 20 km 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.[34]

Another possible explanation is that fleet rationalization was much more successful with the SITM reforms in intermediate cities than in Bogota. As mentioned in Section 2, the original plan for the first phases of Transmilenio was to scrap 5,000 of the 22,000 buses of the conventional fleet (Echeverry et al., 2005), a proportion (23%) of the same order of magnitude as that achieved with the SITM reforms (see Table 8). However, in Bogota, in the end only 1.410 buses were scrapped (6.4%) probably avoiding the negative impacts of a sharp supply reduction.

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.

[31] 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.

[32] 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.

[33] It may also be that the specific design of the infrastructure in these cities did not allow for the full potential of these systems. For example, in most intermediate cities the segregated bus corridors only had partial or no overtaking lanes, limiting the increase in speeds that vehicles could achieve.

[34] For example, for a 10 km trip in the BRT corridor, with pre-reform speeds of 15 km per hour, and an increase of 20% in bus velocity, the reduction of in-vehicle time would only be 6.7 min. Since waiting time costs are at least double the value of in-vehicle time, it would take just an additional 3.3 min of access or waiting time — due 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 min of additional access and waiting time for the passenger to be made worse off. In contrast, for a 30 km trip in the corridor, the equivalent values of additional access and waiting times would be 10 and 17 min, respectively.

First, an excessive optimism born from 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.[35] It is also probable that during this period the demand for transit services became 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*), a share of the infrastructure investment, as well as conventional fleet scrapping programs. Since raising fares was not politically feasible and there were no operational subsidies considered for these reforms, 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 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, current financial restrictions impede increasing supply.

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, Lima and the SITP reform in Bogota. 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, they are implicitly 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 (Doña and Morandé, 2007; Gómez-Lobo, 2012). Fleet size was reduced from some 8,000 buses prior to reform, to 4600 at the design stage (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 upheaval that reverberates to this day. 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.

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 in the generalized cost of travel 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.

Another example is the SITP reform in Bogota, introduced in 2014 aimed to integrate, formalize and improve the transit sector outside of the Transmilenio BRT network. This reform did not contemplate any bus priority infrastructure but it did reduce the fleet size.[36] As expected, SITP demand has not met projected levels.[37] (Beltran et al., 2013) estimate that the SITP reform increased the generalized cost of travel in transit (expressed in minutes) from an average of 69 before reform to 79 min after reform.

Thus, the Colombian experience with SITM reform evaluated in this paper provides important lessons for transit reforms in the rest of the Latin American region and the developing world in general. The impetus for reform stems from the problems associated with the low quality traditional systems that operate in the major cities of these countries. These systems are characterized by informal operators, negative atmospheric and noise pollution externalities, hazardous driving practices as drivers compete for passengers in the streets and old and low quality buses.[38] These problems are real and will continue to motivate transit reforms in developing countries. In light of the results of this paper, how can the design of these reforms be improved to achieve successful outcomes?.

For Colombia, after almost two decades after a national urban transport policy (PNTU) was introduced, it is high time to rethink this policy. In the case of cities that already have a SITM in operation, the options are rather limited. Frequency and coverage must be increased, but this is costly. Realistically, the only way to fund the needed additional supply is with some type of capital or operational subsidy.[39] Another option worth exploring is for feeder services to use the BRT corridors in order to reduce costly transfers for users.

The PNTU also calls for reform in smaller cities with less than 600,000 inhabitants. These reforms, called SETP, have yet to be implemented. They do not consider dedicated bus priority infrastructure. Therefore, the fleet and network rationalization in these

[35] 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.

[36] According to Leonardo Cañon-Rubiano, ex-Director of Operations of Transmilenio, the total fleet size decreased from 18,339 before reform to 13,226 after the SITP reform (personal communication) a drop of 28% similar to the SITM reforms.

[37] Currently it is estimated that SITP demand is approximately 32% of ex-ante projections (Leonardo Cañon-Rubiano, personal communication).

[38] Excess supply contributing to congestion has also been diagnosed as a problem of traditional systems, although the results of this paper suggest that this issue must be revisited.

[39] 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.

cases is likely to produce an 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. Unless sufficient funds are available to guarantee an optimal level of supply, the SETP reforms should be scrapped.

For future reforms in Colombia and the region, there are several options that should be considered. First, reduce the costs of these reforms by 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 renovation for used buses).[40] By lowering costs, there will be less pressure to reduce fleet size and coverage. Second, strong consideration should be given to light BRT systems with open bus priority infrastructure, particularly in smaller and intermediate cities. There are several successful experiences in the region where policy has been to invest in dedicated 'open' infrastructure where buses from 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 have to make costly additional transfers to complete their trips. The experience of Buenos Aires (Argentina) and smaller cities such as Leon (Mexico) and Concepción (Chile) with open bus priority infrastructure are worth analyzing in this respect. Third, other instruments could be used to tackle some of the negative externalities of conventional transit services without having a full fledged reform; for example, a fleet renovation program aimed at improving vehicle quality. Finally, if an ambitious reform is to be undertaken, then it is crucial to consider capital or operational subsidies from the start so that adequate supply and coverage levels can be guaranteed.

There are possibly other lessons that can be extracted from the SITM experience in Colombia than those presented in this paper. Further research should explore possible differences in the impact of SITM reform among cities due, for example, to specific design features, city-size or the timing of reform with respect to other cities. From a methodological point of view, attempts should be made to study whether there are dynamic impacts using some type of event-study methodology (see for example Abraham and Sun, 2018). Finally, other ex-post impact approaches can be used, such as synthetic control groups (Abadie et al., 2010), that may be more robust to the violation of the common trend assumption, in order to test whether the results from this paper are robust across methodologies.

Appendix A. Average value of the SITM variable for cities that implemented reform

In order to evaluate the average impact of reform on the relevant variables from the econometric models it is necessary to multiply the estimated coefficients by the average value of the SITM variable for those cities that undertook reform. For this purpose. the following table presents these average values. It must be borne in mind that since reform was only undertaken in the largest cities, these averages are the same irrespective of whether the full sample is used or only the sub-sample of largest cities. Also, the averages from the 2007 to 2018 sample differ from the averages for the 2005–2018 sample because Pereira is not included in the former.

Sample	Without Bogota	Without Bogota and Medellin
January 2005 to March 2018	0.0405822	0.0462026
January 2007 to March 2018	0.0374003	0.0427272

Appendix B. Placebo regressions and the common trend assumption

In order to attribute the econometric results on transit demand to the treatment (SITM reform) there must not be other confounding effects among treated and control groups. That is, a different time trend in the treated from the untreated observations prior to treatment. In the impact assessment literature this is often called the common trend assumption. In the staggered difference in difference model used in this paper, Goodman-Bacon (2018) shows that the common trend assumption is sufficient but not necessary to obtain unbiased estimates of the true impact of treatment on the treated. A weaker condition is required in this setup. Since this estimate is a weighted average of various comparisons between treated and several control groups, the common trend assumption could be violated for each comparison group but these errors average out in the aggregate.

In spite of the above, in what follows we assume 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

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

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.

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