INSTITUTO DE ECONOMÍA

DOCUMENTO de TRABAJO

408

2011

Transport Policies in Latin America

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www.economia.puc.cl • ISSN (edición impresa) 0716-7334 • ISSN (edición electrónica) 0717-7593

Versión impresa ISSN: 0716-7334
Versión electrónica ISSN: 0717-7593

PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
INSTITUTO DE ECONOMIA

Oficina de Publicaciones
Casilla 76, Correo 17, Santiago
www.economia.puc.cl

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Documento de Trabajo Nº 408

Santiago, Diciembre 2011

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Enrique Ide Carvallo † Pedro Lizana ‡

May 2011

Abstract

The issues of air pollution and traffic congestion in Latin America have been growing increasingly important since the end of the 20th century. The latter may help explain why several cities around the continent have tried different combination of public policies with varying degrees of success. We describe the policies that outline the Latin American experience in this matter and hope to be a useful reference to subsequent research in the area.

*The information presented in this report has been acquired mainly from sources on the internet, thus the authors are not responsible for the content in the case of a lack of information.

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Part I
Introduction

The issues of air pollution and traffic congestion in Latin America have been growing increasingly important since the end of the 20th century. The surge in travel times, the record level of airborne pollutants measured in several cities, and an ever-growing world-wide environmental conscious, among many others, have led both issues to occupy a prominent role in the everyday public debate.

The latter may help explain why several cities around the continent have tried different combination of public policies with varying degrees of success. Measures taken range from what we have called "Road Space Rationing" (e.g. Mexico City 1989), the most common instrument used, to policies aimed at improving the Public Transport Systems (e.g. the Colombian Transmilenio, Bogotá 2000).

One important fact, however, makes the Latin American experience in this matter so unique compared to the worldwide trend: the dominance of command-and-control policies as opposed to incentive-based ones. Indeed, Governments have been reluctant to introduce price mechanisms such as congestion charging (despite the favorable experience of cities like London and Stockholm) or vehicle sales and possession taxes (as for example in Singapore). The political economy of why this is so may be a fruitful area for future research.

The scope of the present article however is far more limited and humble. We confine ourselves to describe the different policies that outline the Latin American experience in this matter and hope to be a useful reference to subsequent research in the area.

Part II

Road Space Rationing

1 Bogotá, Colombia

1.1 Pico y Placa (*Peak and Plate*, August 1998)

Introduction of the Program

Towards the end of the 1990's, local government authorities agreed upon the complete transformation of the transportation system of Bogotá due to high levels of vehicle congestion and air pollution recorded at that time. The new system included introducing a Bus Rapid Transit ("Transmilenio"), rationing the use of cars ("Pico y Placa" and "Dia sin Carro") and encouraging the use of bicycles and walking on newly constructed bike lanes and pedestrian walkways. "Pico y Placa" was implemented in August 18, 1998 with the purpose of reducing traffic during peak hours. They placed restrictions on 40% of private cars from Monday to Friday using the last digit of the cars' license plates. Therefore, every car was banned from circulating twice a week from 7:00 am to 9:00 am and 5:30 pm to 7:30 pm.

Bogotá D.C. Basic Facts (2005)
Population: 7.408.482
0,085 vehicles per person
Source: Plan Maestro de Movilidad 2007

Implementation of the Program

The program was put to effect immediately. Since August 1998 cars within the whole city that did not comply with the restriction were issued tickets. According to former government authorities, public acceptance of the program has increased with time. Evidence can be seen between the difference of issued tickets during 1999 with 310,000 tickets issued and in 2002 with 124,000[1].

Further changes to the Program

In the years following the implementation there were subsequent adjustments to the program. First, the schedule was modified to cover the time frame of 5:00 pm to 7:00 pm and vehicles with license plates registered outside of the city were banned from driving in the city a half of an hour earlier in the morning. Second, an annual license plate rotation was designed to limit the actions taken by car users to avoid the program's restrictions, like getting an

[1] http://www.itdp.org/documents/Seminar/Javier%20Hernandez%20STT.pdf

extra car to use on a certain day. Later in 2004, the program was extended an additional two hours to encompass the hours from 6:00 am to 9:00 am in the mornings and from 4:00 pm to 7:00 pm in the afternoons. Last, in February 2009, the restrictions were put into effect between 6:00 am and 8:00 pm. In 2001, an additional "Pico y Placa", road space rationing, was implemented for public transportation. Like the program for private cars, it sought to reduce the oversupply of buses in the city, which were contributing to congestion. Collective Public Transport or "Transporte Publico Colectivo" (buses, microbuses, "buseta", shared taxis) and taxis were included in this program, with the exception of Transmilenio buses. Operating from Monday to Saturday from 5:30 am to 9:00 pm, the program initially aimed to ban 40% of those vehicles daily, but the restrictions were reduced to 20% because of protests. Currently, "Pico y Placa" for "Transporte Publico Colectivo" is effective from 9:00 am to 5:00 pm, but taxis are still restricted from 5:30 am to 9:00 pm. Additionally in 2006 a "Pico y Placa Ambiental" (Environmental Peak and Plate) was introduced, with the objective of improving air quality. It bans one license plate ending number a day for "Transporte Publico Colectivo" from Monday to Saturday between 6:00 am and 10:00 am, and all trucks of 5 tons or bigger from Monday to Friday between 9:00 am and 10:00 am. Also, certain trucks are prohibited to circulate on selected avenues.

Evaluations of the Program

According to former Bogota authorities, the traffic volume decreased by 25% between 1998 and 2002 in main intersections. Average travel speeds of private cars increased from 14 km/h before "Pico y Placa" was implemented to 22-25 km/h in 2001 and 2002. Furthermore, travel times were reduced by 15%[2]. Vicentini (2010) contrasts these statistics by stating reduction did not exceed 10%. Bocarejo (2008) in Cantillo and Ortuzar (2009), analyze the economic impact of the restriction on 40% of the cars. The author calculated generalized costs (unitary costs) and social costs (marginal costs) with and without the restriction by using demand-generalized cost elasticity of -0.83 and traffic data. Bocarejo concluded that the program results in a social loss of 0.4 million Euros per day (118 million Euros per year) for car users. The extension of the program in 2009 encompassing the entire day increases the losses as users cannot readjust the schedule of their trips. Cantillo and Ortuzar (2009) also show that the number of vehicles registered are considerably superior in Bogota than in the rest of the country.

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1.2 Día sin Carro or Dia del Aire Limpio (*Day Without a Car or Clean Air Day*, February 2000)

Introduction of the Program

Introduced on February 24, 2000 by a decree from the city Mayor, the program banned the circulation of all cars from 6:30 am to 7:30 pm throughout the entire city on that day. It is part of a set of measures with the goal of making the city friendlier, less stressful and less polluted while enhancing mobility. The purpose of this measure is to create public awareness about the importance of sustainable transportation, the difference of the city without cars and the significance of the improvement in air quality. Along with environmental and transportation reasons, "Dia sin Carro" promotes social integration because more people with different social backgrounds have to commute together in buses or share bike lanes.

Implementation of the Program

The introduction of the day without a car in February 2000 was unique for Bogota residents; however, they had experienced similar events before. In the late 1990's up to the present, the city closes more than 100 km of roads for recreational purposes every Sunday for several hours. The first "Dia sin Carro", although criticized by some car users, had a high overall acceptance from the public.

Further changes to the Program

Thanks to the success of the first "Dia sin Carro" in October 2000 the city government carried out a public survey of two propositions. Proposition 1 was for implementing an annual "Day Without a Car" on the first Thursday of February. Proposition 2 aimed to create a legal framework for banning 100% of cars from driving during peak hours by 2015. Both propositions were passed by a majority, especially the "Dia sin Carro", with more than 66% of voters agreeing on it.

Evaluations of the Program

Local authorities argue that there are benefits of reduction of CO (45%) and Ozone (35%) in comparison to a normal day; however, those improvements are offset by the increase in 42% in Particulate Matter (PM)[3]. This increase

[3]http://www.secretariadeambiente.gov.co/diadelairelimpio/noticia.php

is due to the high sulfur content in diesel fuel, which the "Transporte Publico Colectivo" vehicles use and because these vehicles are used more on these days than in any normal day. With high quality diesel, this measure would have positive impact in air quality.

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2 Mexico City, Mexico

2.1 Hoy no Circula (*Today you don't drive*, November 1989)

Introduction of the Program

Record levels of airborne pollutants led the citizens of the capital of Mexico to launch an initiative in 1984 called "Un Dia sin Auto" (One Day without a Car) through an ecological association called "Mejora tu Ciudad" (Improve your City). On November 20, 1989, the city government implemented the program "Hoy no Circula" due to the persistent levels of pollutants. The program consisted of banning every car (except for emergency vehicles and public transportation) in the city from driving one day of the week from 5:00 am to 10:00 pm. The program initially operated during the winter months, the most polluted season of the year. After 1990 it became active all year long. It was also complemented by an emissions inspection program (smog checks) for cars registered in Mexico City every 6 months.

México D.F. Basic Facts (2007)
Population: 8.800.000 (aprox.)
0,17 vehicles per person
Source: Encuesta Origen y Destino 2007

Implementation of the Program

The program was implemented drastically. From the first day, cars in the entire "Distrito Federal", Federal District, that did not comply with the restrictions were issued tickets. It also appears to have been implemented without any shortcomings and compliance to the program was universal since enforcement was strong from the beginning, high penalties were given for violating the restrictions and police controlled effectively (see Davis, 2008).

Further changes to the Program

In January 1991, the ban was extended to public transportation, but only on Saturdays, with each vehicle banned every other Saturday. However, in October 1991, the ban became active on week days instead of Saturdays. Every bus was banned one day of the week (20% of the buses prohibited each day) from 10:00 am to 9:00 pm. In 1992, vehicles using natural gas as fuel were exempt from restrictions. Later in 1997, vehicles produced in 1993 or newer that used a catalytic converter were identified by "holograma 0" (zero hologram) thus exempt from the ban. In 1999, vehicles that complied with international standards for emissions of pollutants (Tier 1 and Tier 2) were granted a "holograma 00" (double zero hologram), making them exempt from the program and giving them the option to carry out smog checks every 2 years instead of every 6 months. By 2008, the program was expanded to include Saturdays. Parallel to these adjustments, in 1998, phase 2 of the "Programa de Contingencias Ambientales" became active, restricting the number of cars depending on the level of airborne pollutant concentrations (normal day, "Precontingencia", "Fase I Contingencias Ambientales or "Fase II Contigencias Ambientales")

Evaluations of the Program

City government authorities state that the implementation of the program was able to reverse the tendency of increasing CO concentrations and maintain them constant during the following three years of implementation despite an increase in the number of vehicles[4][5]. On the contrary, Davis (2008), using data series from 1986 to 1993, argues that there is no evidence of improvements in air quality across pollutants and regression specifications (Ordinary Least Square and Regression Discontinuity design), which included indicator variables such as weather, humidity and wind speeds. It actually instigated an increase in the registration of vehicles and a change in their composition, with older and therefore more polluting vehicles (Eskeland and Feyzioglu, 1997). Davis (2008) also found an increase of pollutant concentrations during the days or hours that the restrictions did not apply, like weekends and non-peak weekdays. He argues that there is no significant association between gasoline sales and "Hoy no Circula" and that there is no relevant increase in subway and public or private bus ridership. Ultimately, although not finding a statistical increase in the number of taxis due to the program, he concludes that the unusually big taxi fleet could have accommodated many of the trips not done by cars by working longer hours, therefore offsetting the environmental benefits of the program since the taxis at the time were amongst the most polluting vehicles.

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3 Santiago, Chile

3.1 Restricción Vehicular (*Vehicle Restriction*, July 1986)

Introduction of the Program

In July 1986, authorities introduced a road space rationing program as a provisory measure to tackle air pollution (mainly PM) for days with critical air quality. The pollutant level to which critical air quality was declared was not formalized by a legal framework and international standards were used as a reference (later were used the results presented by the network of monitoring stations, "MACAM", to declare emergency levels). In the late 1980's, it was decided to maintain the restriction for the winter months (May to August), and in the beginnings of the 1990's, the period was extended to encompass March through December.

Gran Santiago Basic Facts (2006)
Population: 5.818.671
0,1374 vehicles per person
Source: Encuesta Origen y Destino 2006

Implementation of the Program

The implementation of the program has been gradual, since in the first years it was sporadic with a transition in the following years to a permanent schedule.

Further changes to the Program

Since 1992, restrictions became permanent for all cars without a catalytic converter (CC) during the winter months. 20% of these cars were banned every weekday from 7:30 am to 9:00 pm. In days with high level of pollutant concentrations, a "Alerta Ambiental" or "Premergencia" (environmental alert or pre-emergency) is declared, increasing this percentage to 40% and 60% respectively. Trucks were prohibited to circulate within a designated perimeter from 10:00 am to 6:00 pm, and public transportation was banned from 10:00 am to 4:00 pm (De Grange and Troncoso, 2010). From 2001, cars with a CC have been included in days declared "Premergencia" and "Emergencia" (pre-emergency and emergency), restricting 20% and 40% of them respectively. At present time, the permanent restriction for cars without a CC operates from April to August, with 40% of those cars banned every weekday since 2008 to compensate for the relative decrease of cars without a CC.

Evaluations of the Program

According to Fresard (1998), increasing the restricted license plate numbers in days with critical air quality reduced traffic by barely 5%, which is far less than was expected. This demonstrated that people used methods to evade the restriction, including buying a second car. Also as the ban only considered cars without a CC, users with lower incomes that commonly own this type of car were the most affected by the policy. Using regression analysis techniques with 2008 data from car, bus and metro trips, De Grange and Troncoso (2010) analyzed the impact that the restrictions on both type of cars (with or without a CC) had on private and public transportation trips. They conclude that the permanent restriction on cars without a CC does not reduce car trips, but the additional ban on cars with a CC ("Preemergencia" days) reduced car traffic by 5.5%, which is significantly less than the 25% expected (20% of cars with CC and 60% of cars without CC). This could be explained by the fact that many households have two or more cars and because people tended to adjust the schedule of their trips in relation to the starting and ending hours of the restriction. Also during "Preemergencia" days metro trips increase by 3%; however, bus trips do not show any significant increase.

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4 São Paulo, Brazil

4.1 Rodizio Estadual (*State Rodizio*, August 1996 - September 1998)

Introduction of the Program

Road space rationing policy adopted as an emergency measure by the State Secretariat of Environment to reduce atmospheric pollution during winter months. It covered 10 municipalities (including the Sao Paulo Municipality) of the Sao Paulo Metropolitan Region (Greater Sao Paulo). Initially, only private cars were restricted with daily schedules from 7:00 am to 8:00 pm, and in 1997, trucks were prohibited to circulate inside a specific area. The program was suspended after 1998.

Cidade do Sao Paulo Basic Facts (2005)
Population: 10.766.673
0,496 vehicles per person
Source: Prefeitura do Sao Paulo

Implementation of the Program

In 1995, the program was implemented voluntarily for a week (20% of cars restricted every weekday), and resulted in an average 38% compliance rate for that week. Then, in 1996, it was mandatory only for the month of August (excluded buses and trucks) with tickets of US$100, resulting in a 95% compliance rate (Jacobi et al, 1999). In 1997 and 1998 the program included trucks and operated from late June to September with compliances of 90% in mornings and 85% in afternoons in 1997. Therefore the implementation of the program was carried out gradually.

Evaluations of the Program

As cited by CETESB/SMA (1998), emissions reductions for 1997 were estimated in 42,460 tons, 3,440 tons and 200 tons of CO, NOx and PM respectively[6], with an accumulated reduction of CO of 19% until 1998[7] (CETESB/SMA, 1999). Using data from air quality monitoring stations they were able to make a comparison between 1997 data and observations from 1991-1995 in the same period of the year. Results show that, in

[6] http://www.comitelc.airelimpio.org.pe/inicia1.htm

[7] http://www.nossasaopaulo.org.br/portal/files/ProblemasAmbientaisUrbanos.pdf

terms of complying with air quality standards, the restrictions had marginal benefits for Ozone and improvements of 4.3% for PM and 10.8% for CO[8] (CETESB/SMA, 1998).

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4.2 Operação Horário de Pico (*Municipal Rodizio*, October 1997)

Introduction of the Program

In addition to State Rodizio, the Municipal Rodizio was introduced in 1997 with the objective to reduce traffic and increase mobility during the peak hours in the Sao Paulo Municipality (city center). Initially operated from February to June and October to December; the months that State Rodizio was not active. During those months, the cars with the license plate ending number matching the restricted two digits per weekday were prohibited to enter the city center from 7:00 am to 10:00 am and 5:00 pm to 8:00 pm.

Implementation of the Program

The implementation of the program in 1997 fit with the State Rodizio, since when one finished the other started (except for Januray due to school holidays). Unlike State Rodizio, which included the Sao Paulo Municipality and 9 others, the Municipal Rodizio covered an area within the inner ring road in the Sao Paulo Municipality.

Further changes to the Program

In 1999, with the end of State Rodizio, it became permanent (all year round) for all private cars. Since June 2008, trucks are included too.

Evaluations of the Program

The city's traffic management agency ("Companhia de Engenharia de Tráfego" or CET) conducted a field survey to monitor traffic performance before and after the implementation (late 1997 and beginning of 1998) on two important avenues of the city. Some of their results are presented in Biezus and Rocha (1999) and Câmara and Macedo (2007). They show that travel time decreased by 18% and average speed increased by 23% in the mornings and 24% in the afternoons. Also the congestion queue length (CQL), a concept used to quantify congestion, diminished 37% during the morning and 26% during the afternoon peak hours, with an overall daily reduction of 18% . However, in 1996-1998, the car modal split increased as before, and Biezus and Rocha (1999) show concerns about the possibility of the public buying an extra car to evade the permanent Rodizio[9]. Similarly, Câmara and

[9]http://www.konsult.leeds.ac.uk/private/level2/instruments/instrument009/l2_009c.htm

Macedo (2007) state that "the early reductions in traffic levels were soon offset by an increase in the city's vehicle fleet from an estimated 3.5 million vehicles in 1997 to approximately 5 million in 2003". Similarly, according to Cambridge Systematics (2007), a significant increase of 33%, between 1997 and 2007, in the number of vehicles demonstrates that the Rodizio had not been effective enough to reduce car sales. However, in July 2007, the restriction was removed only to be immediately implemented again because the congestion levels rose drastically. Cambridge Systematics (2007) concludes that the impacts of Rodizio have been difficult to quantify due to lack of other independent and more recent studies.

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5 Medellín, Colombia

5.1 Pico y Placa (*Peak and Plate*, February 2005)

Introduction of the Program

A road space rationing program was introduced in early 2005 with the goal of increasing mobility and reducing traffic. Every weekday 20% of private cars were banned from circulating between the hours of 6:30 am to 8:30 am and 5:30 pm to 7:30 pm. At the same time 10% of the taxis were restricted from 6:00 am to 8:00 pm. For cars, the license plate numbers affected daily were rotated every semester and taxis every month.

Area Metropolitana de Medellín Basic Facts (2005)
Population: 3.729.970
0,1411 vehicles per person
Source: Alcaldía de Medellín

Implementation of the Program

The program encompasses the Medellin Municipality, which is located inside the Medellin Metropolitan Area, and it has been mandatory since it was implemented.

Further changes to the Program

In the second semester of 2008, the city administration extended the program to include 20% of two stroke motorcycles and increased the amount of private cars banned to 40%. The decision was made to overturn the increase in traffic levels.

Evaluations of the Program

Posada et al. (2009) in Cantillo and Ortuzar (2009), argues that in the short term (1 year) there is a decrease in congestion and pollutant indicators such as NO2, SO2 and PM10. Contrary to short term, in the medium term (2 years) pollution rose again, in some cases, to higher levels than before the implementation of the policy. This occurred because of an increase in the registration of older vehicles. Similarly, Sarmiento and Zuleta (2009) in Cantillo and Ortuzar (2009) demonstrated that after the implementation of the program the city did not have drastic traffic peaks as before, mainly because people rearranged their trips around the restrictions. Also, they carried out a traffic survey before and after the introduction of the program in nine important intersections. They concluded that after the first year, traffic levels decreased, but two years later they returned to pre "Pico y Placa" levels. This demonstrated that the policy did not have an affect; it actually backfired, because it encouraged people to buy older and more polluting cars to evade the restriction.

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6 San José, Costa Rica

6.1 Restricción Vehícular (*Vehicle Restriction*, August 2005)

Introduction of the Program

A road space rationing policy was implemented in 2005 with the objective of reducing gas consumption due to the high price of oil. It was suspended in June 12, 2009 by a judicial mandate, which resulted in a rapid increase of congestion (Osakwe, 2010). The program was re-implemented on July 21, 2009 with the goal of reducing congestion and air pollution.

Provincia de San José Basic Facts (2003)
Population: 1.435.447
- vehicles per person
Source: Municipalidad de San José

Implementation of the Program

When it was initially implemented, two license plate ending digits were restricted per day from entering a specific area inside the San Jose Metropolitan Area from 7:00 am to 8:30 am and from 4:00 pm to 5:30 pm. Fines for noncompliance were close to $US 10.

Further changes to the Program

In June 2008, the specified perimeter was expanded ("Circunvalacion" Boulevard) due to the continued increase in oil prices. In July 2008, in order to further reduce consumption, authorities extended the schedule to encompass the hours of 6:00 am to 7:00 pm. Heavy trucks were restricted as well, but during peak hours only. By 2010, fines increased to $US 55. Currently, the operating times have been modified to include peak hours only, from 6:00 am to 7:30 am and 4:30 pm to 7:00 pm. Authorities are evaluating which schedule should be maintain.

Evaluations of the Program

According to Osakwe (2010), premium gasoline sales decreased between 12% and 15%, while regular gas and diesel sales stayed constant. The author says that this could imply that there was not a substantial effect in the bus modal share because they are the primary diesel consumers. Osakwe (2010) stated that it could have had a greater affect on car users with lower income as they were forced to rearrange their transportation as opposed to high income car users who tend to have more than one car.

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7 Quito, Ecuador

7.1 Pico y Placa (*Peak and Plate*, May 2010)

Introduction of the Program

Following the continent's trend and due to an increase in vehicle congestion and travel times, Quito was the last of the Latin American cities to implement a Road Space Rationing Policy. The "Pico y Placa" program followed closely the Colombian experience (hence the name) restricting the circulation of privately owned vehicles in a delimited urban area, between 7:00 to 9:30 A.M. and 16.00 to 19.30 P.M. in weekdays, based on the last digit of its license plate. The program is however encompassed within a more ambitious long-rung city transportation policy called the "Plan Maestro de Movilidad 2008-2025" (Master Transport Plan 2008-2025), whose main goals are to *"1. Search for more efficient and safe journeys; 2. Improve the quantity and quality of the public transportation system; and 3. Ensure and improve connectivity of different urban areas".*

Distrito Metropolitano de Quito Basic Facts (2007)
Population: 2.047.900
0,18 vehicles per person
Source: Plan Maestro de Movilidad 2007

Implementation of the Program

The program was put into effect immediately on May 3rd of 2010 by an official decree of the city Mayor. Initially it had an evaluation period of eight months. Failure to comply with the policy implied tickets ranging from 80 to 240 US$ and the vehicle's confiscation for 1 to 5 days depending on the number of previous offenses.

Evaluations of the Program

According to Quito's authorities during the program's first month of application preliminary evidence indicated that traffic volume had effectively decrease in the most important avenues of the city. Moreover, average vehicle speed seemed to have increase between 20% and 40%, while CO levels apparently diminished in comparison to previous months. According to the same sources, there was a high public acceptance of the measure. More than 90% of a survey respondents agreed that the policy should be maintained while nearly 70% though that the city experienced less congestion than in the previous two months. The "Pico and Placa" policy became permanent in 2011.

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Part III
Bus Rapid Transit Systems

1 Bogotá, Colombia

1.1 Transmilenio (December 2000)

Introduction of the Program

This Bus Rapid Transit System was introduced in December 2000, based on the model used in Curitiba. The system replicates a subway, but above ground using buses. Passengers pay at the entrance of the station using a smart card, cross a turnstile and wait inside the station for the bus. There are two types of buses: feeder and trunks (articulate and bi articulate). Trunks circulate on main avenues using exclusive lanes and feeder buses carry people to their destinations in further away neighborhoods using regular lanes. Fares are integrated between both types of buses. Bogota operates a parallel public transportation system to Transmilenio (TM) called "Transporte Publico Colectivo" (TPC) or Collective Public Transport, which consists of buses, microbuses and "busetas". Currently, the dominate pollutants in the city are Particulate Matter (PM) 2.5, 10 and Ozone, which are associated with the TPC and cargo transport.

Implementation of the Program

Initially the system had two trunk lines, which covered "Avenida Caracas" (Caracas Avenue) and "Calle 80" (80 Street). Opposite to what happened in Santiago, Chile, where the entire public transportation system was changed in one day, in Bogota, the TM implementation was gradual. It started with Phase 1 and allowed the TPC buses to operate, and it is expected to finish between 2028 and 2031 with Phase 8, by which the system is expected to cover the entire city.

Further changes to the Program

The system now has nine trunk lines, 83 feeder lines and 84 km of lanes constructed exclusively for trunks buses. Trunk lines transport on average 1.5 million passengers per day[10].

Evaluations of the Program

Expert Eduardo Behrentz says that the if TM gets to Phase 4 (more than 2,000 buses circulating moving 50% of the city's population) the environmental benefits would be similar to the benefits obtained from improving

[10] http://www.transmilenio.gov.co

the quality of diesel (estimated to be a reduction 50% of air pollution), but the difference would be the time it takes[11]. According to Behrentz (2009), this would be the result because the TPC buses and trucks emit considerably more PM than the TM buses. The author also states that a combination of a more organized transit system, including more TM feeder and trunk buses, with better quality diesel and particle filters could imply a reduction of 80% of emissions within five years. Cervero (2005) argues that after a year of the implementation of TM, there were registered average travel time reductions of 32% in buses. On the fifth anniversary in 2005, the transport system was associated with a 40% reduction in air pollution.

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2 Santiago, Chile

2.1 Transantiago (February 2007)

Introduction of the Program

During the 1980s, authorities decided to liberalize and deregulate the public transportation system (called "Micros Amarillas" or yellow buses), expecting that the market would increase bus frequencies, quality of service and reduce fares. Indeed there was a sustained increase in the number of buses, which generated in higher frequencies and more coverage of the city. The main benefits of the system were that 98% of the city population lived within eight blocks from a bus service, only 18% of trips required transfers and average waiting times were four minutes (Díaz et al, 2006). However, fares kept increasing and quality of service did not improve because the competition for price and quality was low as a result of low fare-demand elasticity (because waiting time for buses is also a cost). The system also created many other problems. The most relevant problems included long travel times due to bus network inefficiency, congestion because of oversupply and overlapping of bus lines in the city center, high rate of accidents as result of in street competition for passengers (drivers were paid proportional to the amount of passengers carried) and severe atmospheric and noise pollution as a result of the oversupply and the old age of the buses (Díaz et al, 2006). Also, the Metro system had a very low percentage of use because passengers had to pay to connect to it. In the 1990s, authorities introduced regulations and started a bidding process for bus lines. However, there is evidence of collusion in the 1998 bidding process, which resulted in a continued increase in fares. In 2000, bus property was atomized, with each operator owning on average only two buses (Díaz et al, 2006). The main problems of the system still persisted in the following years, so government authorities decided to restructure it completely to create an integrated, efficient and modern system, using Transmilenio and Curitiba's BRT as examples. The system included dividing the city into ten zones, with feeder buses serving each zone, trunk buses using the main arteries of the city and the Metro being the backbone. They planned to have nine operators for feeder services and five for trunk services. Fares were integrated between buses and the Metro and passengers had to pay using a smart card. The bus fleet would be updated with modern, articulate buses, and they would carry GPS so as to regularize headways and control the fleet. Also, it was expected to have a modern information system and the construction of segregated and exclusive lanes for the circulation of buses. The system was initially constrained to finance itself. Previous to the implementation, a new Metro line was inaugurated.

Implementation of the Program

Since October 2005, some of the new buses were already operating parallel to the previous system, with the final implementation occurring on February 10, 2007, considered the Big Bang by experts. It was a radical change as all the "Micros Amarillas" stopped circulating giving way to the new system, which was supposed to operate fully from that day on. Along with the implementation, a crisis emerged because many defects became evident. First, as operators lacked incentives to put their buses into circulation, a very low percentage of buses were operating on the first days. This produced discontent among users, as there were long waiting queues at critical points in the city; travel times increased and buses were full to their maximum capacity. Second, the machines that validate the smart cards did not work, so the system was free for some days, generating a huge financial loss. Some peripheral areas were not covered by routes making people walk long distances. Much of the infrastructure dedicated to the buses (stations, segregated and exclusive lanes) was inconveniently not ready at the time of implementation. Some contingence measures were taken, like fines to operators that did not comply with their contracts, older buses painted and used to offset the lack of new ones, express services to satisfy demands for longer trips, the creation of exclusive lanes, the modification of bus services and the designation of pay zones similar to subway stations in order to organize and make the loading and unloading of buses faster.

Further changes to the Program

Since it was implemented, the system has suffered subsequent changes. Bus structure was modified allowing more flexibility of the services, more services were created and infrastructure was constructed for buses (stations and segregated lanes) and for Metro (line extensions). Online information services and contract enforcement have improved too. There have been regular discussions on the amount and nature of the permanent subsidy to the system. Fares have increased to almost double as their initial cost. A recurring problem of the system is the high percentage of evasion.

Evaluations of the Program

Centro Mario Molina Chile (2008) states that at a global level, PM10 and NOx increased between July 2006 and July 2007; however, a fall in ultrathin

PM and soot at the street level was observed. Also bus flow decreased, associated to the fall in soot, but car traffic increased. Using models, the authors found changes in the composition of street level NOx, with a decrease related to buses, although it was offset by the increase in car flow. One of the reasons why benefits at street level are not transferred to a global level is because the official air quality monitoring network considers the particle mass and not their quantity. A decrease in ultrathin PM is almost imperceptible in PM10 as the former have less mass. Also, there was an increase during both years in PM, NOx, SOx emissions (with Volatile Organic Compounds they are precursors of secondary PM) related to private transport and other industries.

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3 Mexico City, Mexico

3.1 Metrobus (June 2005)

Introduction and Implementation of the Program

In 2002, as a result of a cooperation agreement between EMBARQ-The World Resources Institue for Sustainable Transport and the city government, it was created the Mexico City Center for Sustainable Transport. Between 2003 and 2004, this Center and local authorities carried out studies for designing a Bus Rapid Transit system, with the objectives, amongst others, of improving mobility, air quality and quality of life in Mexico City. The system used Bogota's Transmilenio as an example. In late 2004, it started the construction of Metrobus Line 1 on the northern section of Insurgentes Avenue. Line 1 was inaugurated on June 2005, with 36 stations and a longitude of 20 km.

Further changes to the Program

In March 2008, the extension of Line 1 nine kilometers to the south started operating. In December 2008, Line 2 in Eje 4 Sur was inaugurated. Line 3 in Eje 1 Poniente was opened in February 2011, and there are two more lines projected for the future, Line 4 and Line 5, for 2011 and 2012, respectively.

Evaluations of the Program

According to Metrobus sources, passengers travelling in Metrobus Lines 1 and 2 have reduced their travel times by 40% in comparison to non Metrobus users. Also, both lines reduce 80,000 tons of CO2 every year and contribute to improve air quality as their buses comply with Euro III and IV standards and use low sulfur diesel[12]. According to EMBARQ 2009 and Global Mass Transit Research, the operation of Lines 1 and 2 of Metrobus have instigated an important decrease in NOx, PM 10, CO and CO2 emissions. Also, both lines have implied commuter time savings of 30%[13].

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4 Quito, Ecuador

4.1 Metrobús-Q (1995)

Introduction and History

Even though by the beginning of the 1990's the State was already an active participant, by both regulating and providing transport services, Quito's Public Transport System was still dominated by private operators (mostly cooperatives and enterprises). According to authorities, the result was (and still is, but to a lessen extent) a "poor quality service in an anarchic environment, with numerous management inefficiencies, and a constant conflict for passengers" (Plan Maestro de Transporte 2002). This catalyzed the creation of the *Unidad de Estudios de Transporte* (UET, Unit of Transport Studies) in 1990, which initialized the studies for the *Plan de Racionalización del Transporte Público de Quito* (the first of the city's Master Transport Plans) and laid the foundations of the *Trolebús*, the first public transport exclusive corridor. This eventually led to the formulation of the more complete *Metrobus-Q* plan.

Description

The *Metrobus-Q* system is currently conceived as a series of exclusive public transport corridors localized in Quito's main vehicular axes. Its central goals are "1. Consolidate a public-private alliance with operators; 2. Improve access and quality with a new structure of services; 3. Modernize the operation of the public transport system", among others (Innovar.Uio – *Empresa de Desarrollo Urbano de Quito*). The system has been divided between "first" (*Trolebús* and *Ecovía*) and "second generation" lines (*Corredor Central Norte, Corredor Sur Oriental* and extensions of the first generation lines). As most of the Bus Rapid Transit systems implemented in Latin America, it was inspired in the famous case of Curitiba, Brazil (see page 36).

Implementation of the Program

The implementation of the program has been extremely gradual, to the point that the "conventional", privately owned system of operators is still responsible for the 77% of all public transport trips (Innovar.Uio – *Empresa de Desarrollo Urbano de Quito*). The program officially started its operation with the opening of one of the first generation line known as the *Corredor Central de Trolebús* (also known as the red line) in 1995, a 16 kilometers long exclusive bus lane between the stations of *La Y* and *El Recreo*. In 2001 the second of the first generation lines, the 8.5 km. long *Corredor Nororiental Ecovía* (green line), was opened between the stations of *La Marín* and *Río Coca*. Second generation lines started appearing with the opening of the 23.4 km. long *Corredor Central Norte* in 2004, the *Trolebús* and *Ecovía* extensions and the recently opened *Corredor Sur Oriental* (2011 - 12,1 km.)

Evaluations of the Program

The results have been at best mixed. According to Quito's 2007 Master Plan 54% of survey respondents would only rate the current system as regular. While 52% considers that waiting times are excessive and a 51% that the system insecure. Public perception seems to be consisting with hard facts. Indeed in 2007 during high peak hours, waiting time exceeded 12 minutes while the optimum has been established at 5; the effective passenger/m2 ratio has been 5.6 while the buses are designed for 4. Also, the system has not reached a balance budget operation still needing Municipal Subsidies, and not all infrastructure has been correctly maintained (in 2011 Quito's Municipality has decided to close and rebuild 26 stations in the *Corredor Central Norte*).

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5 Curitiba, Brazil

5.1 Curitiba's Master Plan (1965)

Introduction and History

Curitiba is the capital of the State of Paraná located 400 km. away from Sao Paulo in the southern part of Brazil. According to the Investor's Guide of Curitiba 2010, the city has a population of 1.85 million people, 21.700 R$ (13.800 US$, current exchange rate) of per capita GDP, and is highly renowned for its world-wide famous Rapid Bus public transport system.

The origins of this program dates back to the mid 1960's with the creation of the *Instituto de Pesquisa e Planejamento Urbano de Curitiba* (IPPUC, Curitiba Institute of Urban Research and Planning) and the elaboration of the "Curitiba Master Plan" first implemented for Mayor Jaime Lerner in 1971.

Cidade do Curitiba Basic Facts (2010)
Population: 1.850.000 (approx.)
0,62 vehicles per person
Source: Curitiba Investor's Guide

Description and Key Characteristics

The public transport system of Curitiba is a highly connected network with a rich variety of services. These ranges from rapid non-stop, to high capacity "biarticulated" buses with exclusive lanes and more than 100 feeders lines. The core of the system is formed by 5 main axes consisting 81.4 km of exclusive bus corridors. Interestingly the city's urban planning policy is closely aligned with the transport system, taking into account the distance to the near corridor. The idea is to allow higher population densities in areas closer to the core of the network to guarantee a quick and easy access to the system to the maximum number of people possible.

The system could be described as a public-private joint-venture: while private firms provide the services, the city government defines routes, standards and infrastructure. The short/medium term administration is done by an entity called *Urbanização de Curitiba* (URBS) who is in charge of the coordination, fair collection, revenue distribution, among others, but the strategic, long-run decisions are made by the IPPUC.

The success of the program can be deduced by the intensive use of system by the people of Curitiba despite of being one of the cities with the highest rate of vehicles per person (0.62 compared to the 0.137 in Santiago, Chile for example). Indeed according to the Investor's Guide in 2009, 2.4 million passengers were transported in a daily basis using the public system.

Guiding Principles

Based on the experience of Curitiba, different authors have proposed a variety of guiding principles to ensure the success of a public transport system. A common denominator seems to be the need to complement the design and application of the transport policy with a coherent urban planning and land control program. For example Rabinovitch & Hoehn (1995) argue that an *"Effective urban transportation does not develop in isolation from a city's evolving settlement pattern"* and *"Land use control and the transportation system should complement each other"*. This point has also been stressed by Brinckerhoff (1996).

The first authors also pointed out that a practical approach based on *"smaller, incremental steps toward an explicit long-term goal"*, seems to be more effective than the traditional one where data collection and analytical design generate too long delays before the implementation of the program making most of its models usually obsolete.

Finally, the organization of the system, in particular the creation of a specialized entity (the IPPUC) aimed at designing, implementing and controlling the policy, and the public and private sector close collaboration emerge also as key principle.

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Part IV

Fuel Taxes

1 Chile

1.1 Impuesto Específico (*Specific Tax*, April 1986)

Introduction of the Program

This tax was implemented in Chile in 1986, aimed to collect money for the reconstruction of roads in the aftermath of the 1985 earthquake. The initial tax for gasoline was a fixed charge of 2 UTM/m3 (UTM: Monthly tributary unit, real currency) plus a variable charge that depended on the price that ENAP refinery ("Empresa Nacional del Petroleo) sold to wholesale distributors. For diesel the fixed charge was 1.5 UTM/m3 and the tax applied only for vehicular use[14].

Further changes to the Program

At present, it is theoretically objective goes from environmental and economic efficiency to a mechanism of collecting money supposedly for improving road infrastructure. The tax for gasoline have progressively increased, raising to 3 UTM/m3 in the end of 1988, 4.4 UTM/m3 in 1999, 5.2 UTM/m3 in 2000 and 6 UTM /m3 in 2001. In 2008, a variable component was established that was subtracted from the fixed component of 6 UTM/m3. The tax for diesel has stayed around 1.5 UTM/m3 and is still applied for vehicular use, even though trucks can deduct taxes by using concessionary highways[15]. Parallel to the tax, authorities have used stabilization funds to maintain the price of fuels.

Evaluations of the Program

Using a general equilibrium model-ECOGEM-, O'Ryan, et al (2005) evaluate changes in macroeconomic variables (production, consumption, imports, exports, labor, etc.), distributive variables (income, prices, utilities, etc.), sector level variables (energy, construction, commerce, etc.) and environmental variables (emissions of pollutants) for different increments in fuel taxes. Doubling the tax implied a reduction of PM10 by 16%, NO2 and SO2 emissions by 17%, a 6% fall in CO and a 3% decrease of VOCs emissions. After, they simulated doubling the fuel tax with fewer restrictions to commerce; the results were a decrease in emissions, but in less magnitude than the situation before. Similarly, using ECOGEM-Chile, O'Ryan et al (2003)

[14]http://www.cne.cl/archivos_bajar/ley_18502_impuesto_combustibles.pdf
[15]http://www.institutolibertad.cl/p_ec_261.htm

evaluate the impact of applying a direct tax on PM10 emissions while simultaneously decreasing IVA, Chile's sales tax, to produce a 10% reduction of this pollutant. They obtain the expected decrease in PM10 and an even further decrease in NO2 and SO2. They also compared the direct tax on PM10 emissions with an increase in fuel taxes (decreasing IVA) and concluded that economically and environmentally an increase in fuel taxes is less desirable than a direct tax on PM10. Finally, they simulated a scenario with reductions of 50% of PM10, and arrived at the conclusion that these environmental taxes became more regressive for a bigger reduction of emissions. Parry and Strand (2010) explored the optimal tax for gasoline and diesel so that users of motorized vehicles internalize the externalities they produce. Their results concluded that the optimal tax for gasoline is 265 Chilean Pesos (CLP)/liter and for diesel 244 CLP/liter. These numbers are more than the actual taxes, especially for diesel. The emissions of local pollutants represent almost 20% of the optimal tax that the authors concluded.

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